FEBRUARY 1959

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 51 • NO. 2

Solution to solution: spray solves the lime-feeding problem at Elizabeth, N.J.

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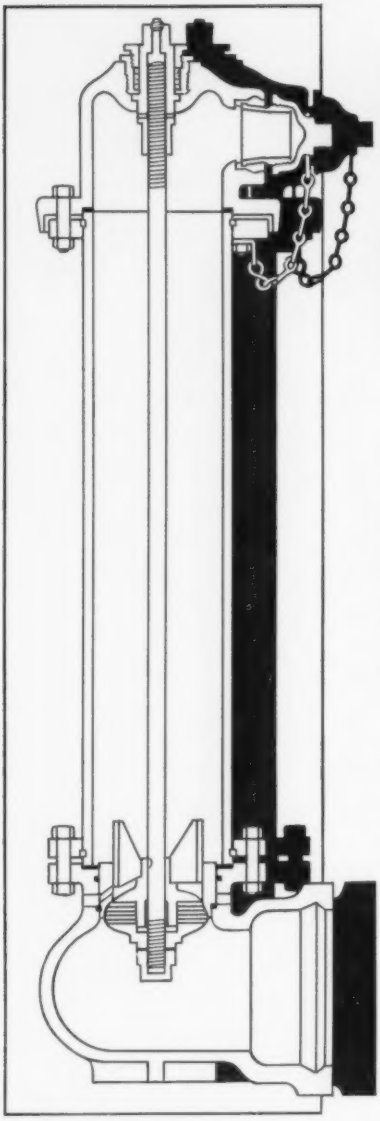

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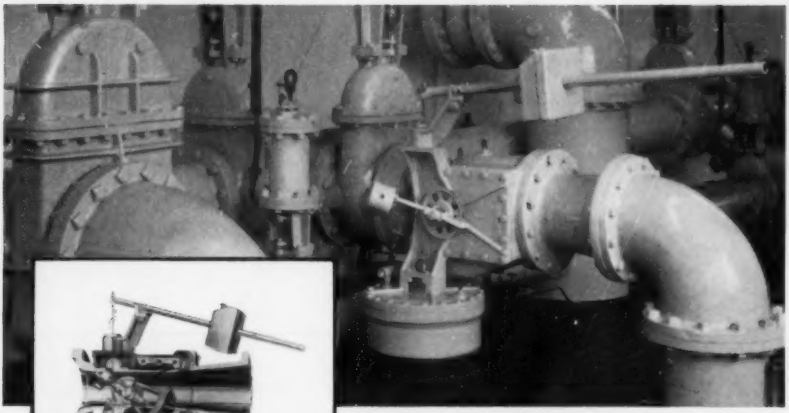

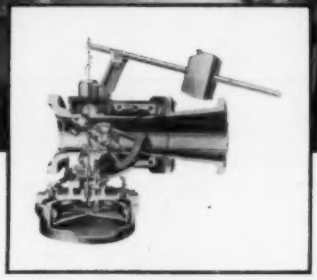

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San Francisco, Calif. Jul. 12–17, 1959

Official reservation forms being mailed to all members are returnable to AWWA postmarked on or after (but not before) noon, Mar. 16.

Coming Meetings

AWWA SECTIONS

Winter-Spring 1959

Mar. 11–13—Illinois Section, at Morrison Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

Mar. 19—New England Section, at Statler Hotel, Boston, Mass. Secretary, J. E. Revelle, Dist. Sales Mgr., Chicago Bridge & Iron Co., 201 Devonshire St., Boston 10, Mass.

Apr. 5–8—Southeastern Section, at Wade Hampton Hotel, Columbia, S.C. Secretary, N. M. deJarnette, Engr., Water Quality Div., State Dept. of Public Health, 309 State Office Bldg., Atlanta 3, Ga.

Apr. 8–10—New York Section, at Powers Hotel, Rochester. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 2222 Jackson Ave., Long Island City 1.

Apr. 9–11—Montana Section, at Jordan Hotel, Glendive. Secretary, Arthur W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

Apr. 15–17—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, Rupert C. Ott Jr., Repr., Neptune Meter Co., 2818—21st St., Columbus.

Apr. 16–18—Arizona Section, at Hi-Way House Hotel, Phoenix. Secretary, Stanford I. Roth, Supvr. of Water Collections, Div. of Water & Sewers, Phoenix.

Apr. 22–24—Kansas Section, at Besse Hotel, Pittsburg. Secretary, Harry W. Badley, Repr., Neptune Meter Co., 119 W. Cloud, Salina.

Apr. 23–25—Pacific Northwest Section, at Vancouver Hotel, Vancouver, B.C. Secretary, Fred D. Jones, W. 2108 Maxwell Ave., Spokane 11, Wash.

May 3–6—Canadian Section, at Queen Elizabeth Hotel, Montreal, Que. Secretary, A. E. Berry, Gen. Mgr. & Chief Engr., Ontario Water Resources Com., Parliament Bldgs., Toronto, Ont.

Jun. 3–5—Pennsylvania Section, at Salem House, Wernersville. Secretary, L. S. Morgan, Chief, Mine Drainage Sec., 413 First National Bank Bldg., Greensburg.

(Continued on page 8)

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★ *O-ring or standard packing*
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Optional break flange gives double protection against impact damage

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NEW SAFETY COUPLING

EDDY VALVE COMPANY
A Subsidiary of James B. Clow & Sons, Inc.
WATERFORD
NEW YORK

Coming Meetings

(Continued from page 6)

Fall 1959

Sep. 9–11—Wisconsin Sec., Milwaukee.

Sep. 14–16—Kentucky-Tennessee Sec., Lexington, Ky.

Sep. 16–18—New York Sec., Upper Saranac Lake.

Sep. 23–25—Michigan Sec., Saginaw.

Sep. 27–29—Missouri Sec., Kansas City.

Oct. 7–9—Chesapeake Sec.

Oct. 14–16—Iowa Sec., Des Moines.

Oct. 18–21—Alabama-Mississippi Sec., New Orleans, La.

Oct. 18–21—Southwest Sec., New Orleans, La.

Oct. 22–24—New Jersey Sec., Atlantic City.

Oct. 28–29—West Virginia Sec., Parkersburg.

Oct. 28–30—Ohio Sec., Dayton.

Oct. 30—California Sec., Bakersfield.

Nov. 4–6—Virginia Sec., Roanoke.

Nov. 9–11—North Carolina Sec., Durham.

Nov. 15–19—Florida Sec., Tampa.

OTHER ORGANIZATIONS

Feb. 15–19—American Institute of Mining, Metallurgical & Petroleum Engineers, San Francisco, Calif.

Mar. 1–6—Texas Water & Sewage Works Assn. Short School, Texas A&M College, College Sta., Tex.

Mar. 2–13—Short courses on "Water Quality Management—Sanitary Engineering Aspects" and "Basic Radiological Health," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Apply to USPHS regional office director or to Chief, Training Program, R. A. Taft Sanitary Engineering Center, 4676 Columbia Pkwy., Cincinnati 26, Ohio.

Mar. 16–25—Short course on "Environmental Health Aspects of Nuclear Reactor Operations," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Apply as above.

Mar. 16–20—National Assn. of Corrosion Engineers, Sherman Hotel, Chicago, Ill.

Mar. 16–20—Western Metal Exposition & Congress, sponsored by American Society for Metals and other technical groups, Pan-Pacific Auditorium and Ambassador Hotel, Los Angeles, Calif. Write: Ray T. Bayless, Asst. Secy., 7301 Euclid Ave., Cleveland 3, Ohio.

Apr. 5–10—5th Nuclear Congress, Public Auditorium, Cleveland, Ohio, including Nuclear Engineering & Science Conference, sponsored by AWWA and other societies; Atomic Energy Management Conference, sponsored by Atomic Industrial Forum and National Industrial Conference Board; Hot Laboratories & Equipment Conference; and Atomfair, sponsored by Atomic Industrial Forum. Write: T. A. Marshall Jr., Mgr., 1959 Nuclear Congress, c/o Engineers Joint Council, 29 W. 39th St., New York 18, N.Y.

Apr. 6–10—American Welding Society, Sherman Hotel, Chicago, Ill.

May 4–8—ASCE Convention, Cleveland, Ohio.

May 5–7—Industrial Waste Conference, Purdue Memorial Union, Bldg., Purdue Univ., Lafayette, Ind.

May 18–20—Symposium on Instrumental Methods of Analysis, sponsored by Instrument Society of America, at Shamrock-Hilton Hotel, Houston, Tex.

New Coagulant Cuts Costs of Water Treatment

Fast Action Permits High Flow Rates

High speed coagulant action of Nalco 614 is especially good news for the many municipal water treating plants now operating over rated capacity. In fact, the extremely fast action of this new coagulant promises better operating efficiency in *any* municipal system.

Characteristics of Nalco 614

Basically, Nalco 614 is a new sodium aluminate coagulant. It has excellent dry feeding characteristics due to a new manufacturing process that produces near spherical granules. It is a fast dissolving, highly soluble material.

Rapid coagulating action boosts equipment capacities, virtually eliminates post-precipitation.

Nalco 614 is being used alone, with lime and soda ash, and with low dosages of common coagulants such as alum or activated silica.

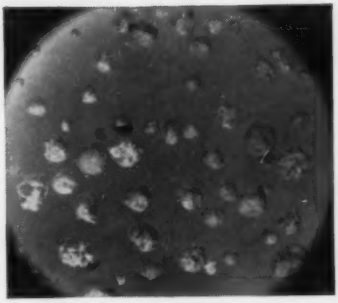
In softening systems, Nalco 614 improves hardness reduction, as well as coagulation. Since it is an alkaline material, lime and soda ash dosages can be reduced.

Plant Reports

There is no substitute for full-scale use of a new product to prove its usefulness and advantages. Here are some of the results that water works report after putting Nalco 614 to work:

"Saved almost $1,000 per Month over the cost of previous treatment, principally alum," says one filtration plant superintendent.

Replaced Alum and Ferric Sulfate at a municipal water plant in Iowa. This plant softens water to 85 ppm. Previous cost of alum, iron, lime and soda ash was $239.00 per day. Replaced 25 parts alum and 50 parts ferric sulfate with only 8 parts Nalco 614. Lime and soda ash dosages also reduced because of 614 alkalinity. Cut overall chemical cost to $150.00 per day; a saving of $89.00 per day — $32,485.00 per year!



Photomicrograph of Nalco 614 particles shows one of the reasons for its excellent handling and dry feeding characteristics: spherical grains that assure free flow through conventional dry feeders.

1 ppm 614 Outperformed 10 ppm Alum according to the experience in a California municipal plant: "Nalco 614 is doing a beautiful job of both coagulation and feeding."

Quotes on Nalco 614 Handling

Here are some typical comments on Nalco 614 handling characteristics:

"I have never seen any material which fed as well and as uniformly as Nalco 614."

"Nalco 614 flows easily, requiring no agitation and no banging on the outside of the hopper."

"It feeds as easy as rice alum. We have been able to whip all of the feeding problems that have plagued us..."

Action for Your Plant

Nalco 614 has a record of results in municipal water treating that comes close to the spectacular . . . and there is no reason why it cannot perform the same way for you. Call your Nalco Representative, or write Nalco direct for prompt action toward Nalco 614 savings and performance in your plant.

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Affiliated companies in Canada, Venezuela, Italy, Spain, West Germany

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Nalco CHEMICALS

PHOTOVOLT
pH Meter Mod. 115

A full-fledged line-operated pH Meter of remarkable accuracy and stability at the low price of

$145

- SIMPLE IN OPERATION AND MAINTENANCE
- FAST AND DEPENDABLE IN SERVICE

Write for Bulletin #225, also for literature on other Line-Operated and Battery-Operated Photovolt pH Meters

PHOTOVOLT CORPORATION

95 MADISON AVENUE NEW YORK 16, N. Y.

Also: Multiplier Photometers, Exposure Photometers for Photomicrography, Hemoglobinometers, Glossmeters, Polarimeters, Foot-Candle Meters, Interference Filters, Mirror Monochromators

WATER IS USUALLY GROWTH PROBLEM NUMBER ONE

For growing communities with new residential or industrial developments, the first problem often to be solved is that of an adequate supply of water. Graver has solved this problem over and over again, for expanding towns like Akron, Indiana. This 100 foot high 150,000 gallon elevated water tank for Akron is one of a large number of tanks, standpipes and reservoirs built by Graver—in sizes from 25,000 to 6,000,000 gallons. For help in solving your water needs, call on Graver, fabricators for over a century.

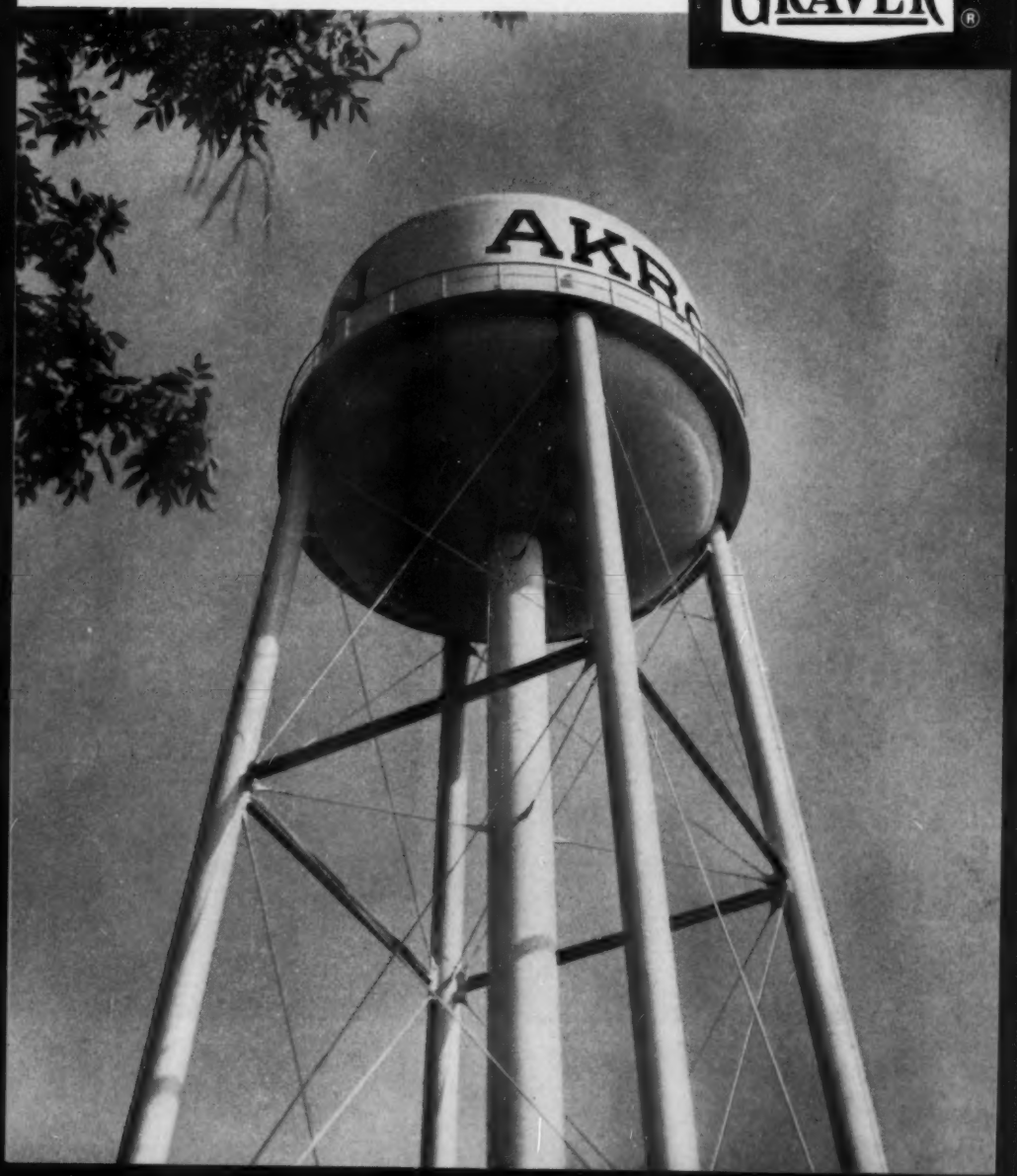
GRAVER TANK & MFG. CO.

DIVISION—UNION TANK CAR COMPANY

Plants and Offices Across America

EAST CHICAGO, INDIANA

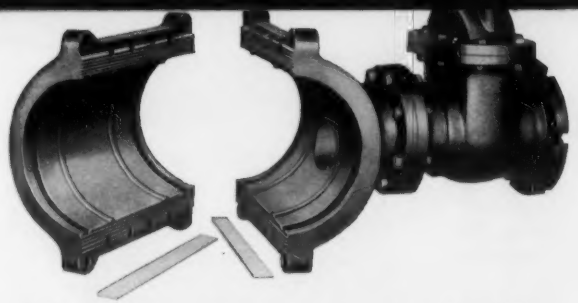
GRAVER®



THERE ARE
MANY WAYS TO
CUT OFF A STREAM
OF WATER

THE BEST WAY IS WITH LUDLOW AND RENSSELAER GATE VALVES!

Because Ludlow gate valves and Rensselaer gate valves assure *ease of operation, watertight closure and years of trouble-free performance.*



Combining simplicity and soundness of design with high quality workmanship, Ludlow and Rensselaer gate valves meet all the requirements of exacting engineers and water superintendents — and exceed A.W.W.A. specifications.

Ludlow and Rensselaer double disc gate valves offer the most complete selection of outstanding design features available today, plus custom design engineering for special applications. Sizes range from 2" to 72"

WRITE TODAY
for the L&R
Gate Valve Catalogs

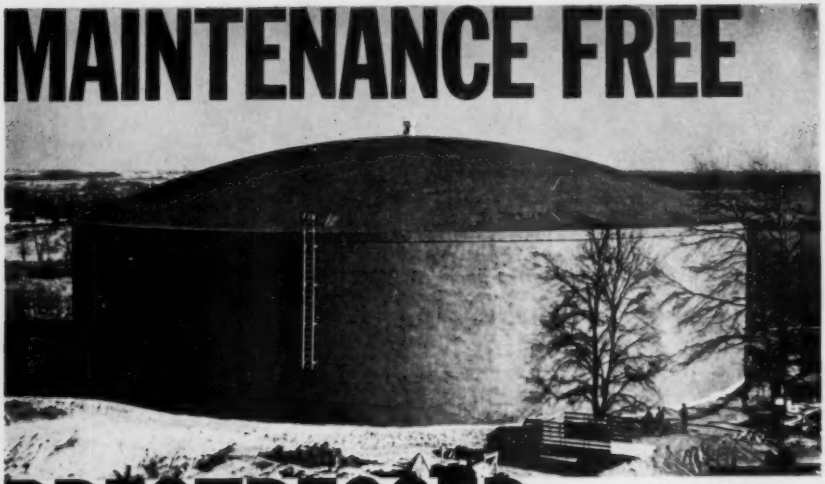
BRANCHLINE CONNECTIONS TO MAIN LINES UNDER PRESSURE are made easier and more dependable by Ludlow and Rensselaer tapping sleeves and valves.

LUDLOW & RENSSELAER

VALVES & HYDRANTS

THE LUDLOW VALVE MANUFACTURING CO., INC., TROY, N. Y.—SINCE 1861

MAINTENANCE FREE



3,000,000 gallon tank, Montgomery County (Dayton), Ohio

PRESTRESSED CONCRETE WATER TANKS

- No maintenance required
- Over 2000 tanks in service
- Owners never return to other types
- Lowest overall cost to community
- 75% construction cost spent locally

If your growing community has a water storage problem, by all means consider a Preload Prestressed Concrete Tank. Overall $ savings to your community can be phenomenal. Call or write today for more information. Send for Bulletin T-22.

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THE CANADA GUNITE COMPANY, LTD.
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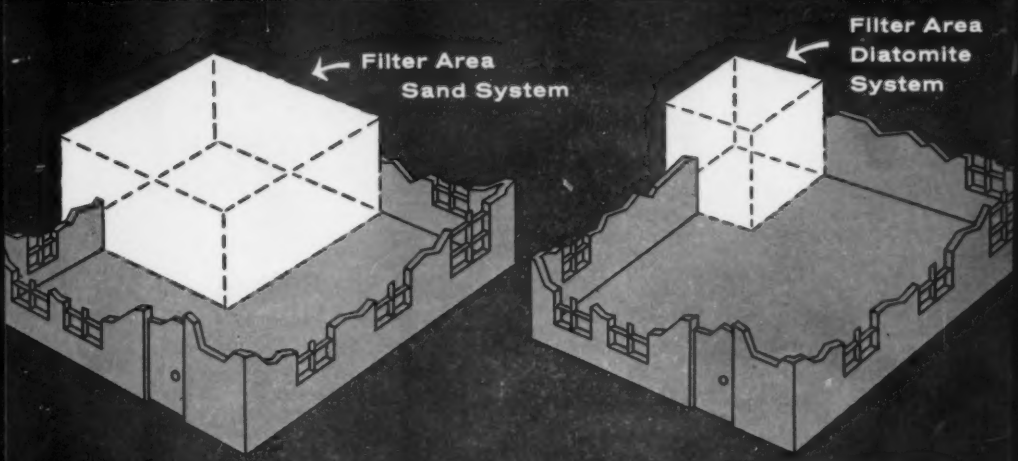
Montreal 16, Canada

WITH CELITE DIATOMITE FILTRATION YOU CAN GET CRYSTAL CLEAR WATER AND...



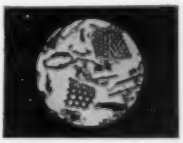
Cut space requirements as much as 75%

A Celite* diatomite filtration system requires only ¼ the housing space that a sand filtration system needs to deliver the same water capacity. Because of this, an actual Celite diatomite filter station was installed by Johns-Manville for only 55% of the cost of a comparable sand filter plant.†

For those communities that wish to increase their present water capacity but must hold down improvement costs, a Celite diatomite filter can in most cases be added right in the existing sand plant. Capacity can be more than doubled without spending a penny for additional land or construction.

Diatomite systems not only save space, but, under comparable conditions, they also improve water clarity. For with Celite, turbidity is usually lower, since more suspended impurities, including all floc, amoebae and algae, are removed. In fact in some cases, turbidity is so low it can't be measured.

Mined by Johns-Manville at the world's largest and purest commercial diatomite deposit, Celite is carefully processed for purity and uniformity. It is available in a wide range of grades to deliver the best practical balance of clarity and flow rate with any suitable filter. For further information see your nearby Celite engineer or write for free technical reprints and illustrated brochure to Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.



Celite filter aids are composed of microscopic irregularly shaped particles like these. 90% of a given quantity of Celite is composed of countless channels and voids that trap the finest impurities while permitting the free passage of clear liquid.

*Celite is Johns-Manville's registered trade mark for its diatomaceous silica products. †See *Comparison Studies of Diatomite and Sand Filtration* by G. R. Bell, Journal American Water Works Association, September, 1956 or write for free reprint.

Johns-Manville CELITE Filter Aids

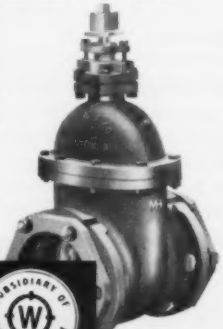
Catherine had NO BATHTUB

Catherine de Medici, luxury loving queen of France, moved her court 90 times in 6 years so that the filthy rooms could be cleaned. The royal palace contained no water pipe nor bathing or washing facilities. Today in the United States, over 80% of homes have bathtub or shower, over 86% have inside toilet.

The American people are using water at greater consumption rate than any other people in all history. Over 250 billion gallons are withdrawn daily from ground, lakes and streams for all uses—an increase of 34% in five years. With population increasing faster than any other Nation on earth, it is estimated that by 1975 there will be 227 million Americans who will require 50% more water than they use today!

The men who build, manage and maintain America's water distribution systems are wide awake. They are aware of future problems and are planning ways and means to meet them.

This Series is an attempt to put into words some appreciation of the water works men of the United States.



M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

SUBSIDIARY OF W WALWORTH

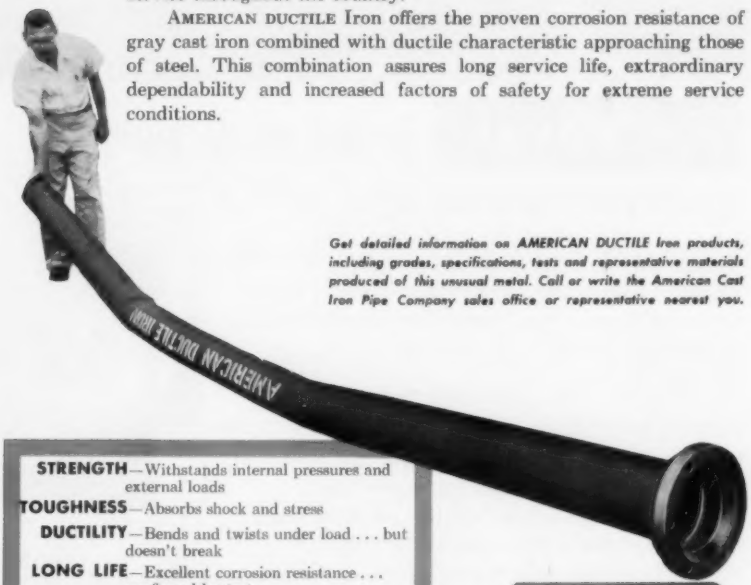
NEW! Cast Iron That Bends Under Stress!

AMERICAN DUCTILE IRON

A new super-service line of pipe, tubing, casing, fittings and special castings has been developed by the American Cast Iron Pipe Company and designed to meet the special service requirements of high internal pressures, heavy external loads and extreme shock. This new line of products is produced of AMERICAN DUCTILE Iron.

Another in a long list of AMERICAN "firsts," AMERICAN DUCTILE Iron products are the first of their type to be manufactured in commercial quantities in the United States. Already widely accepted, many thousands of feet of AMERICAN DUCTILE Iron pipe are now in service throughout the country.

AMERICAN DUCTILE Iron offers the proven corrosion resistance of gray cast iron combined with ductile characteristic approaching those of steel. This combination assures long service life, extraordinary dependability and increased factors of safety for extreme service conditions.



Get detailed information on AMERICAN DUCTILE Iron products, including grades, specifications, tests and representative materials produced of this unusual metal. Call or write the American Cast Iron Pipe Company sales office or representative nearest you.

STRENGTH—Withstands internal pressures and external loads

TOUGHNESS—Absorbs shock and stress

DUCTILITY—Bends and twists under load . . . but doesn't break

LONG LIFE—Excellent corrosion resistance . . . confirmed by tests

AMERICAN CAST IRON PIPE CO.
BIRMINGHAM ALABAMA

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Chicago • Kansas City
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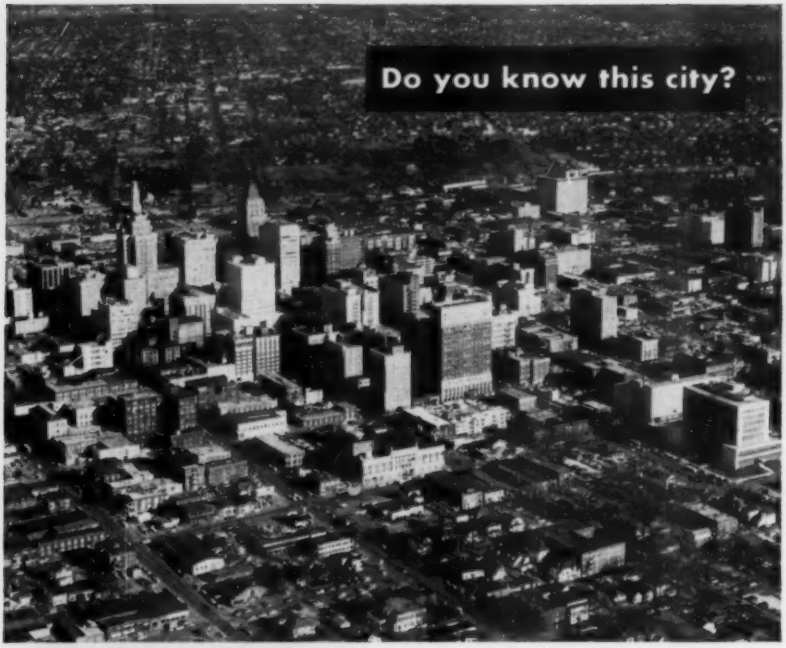

DE LAVAL *water works pumps serve the citizens of...*

Tulsa...In the heart of the oil country, De Laval centrifugal pumps work 'round-the-clock to meet the fast-growing needs of this dynamic community. In other major cities throughout the country, the De Laval name is synonymous with dependable, efficient water works equipment.

Today, in fact, the great majority of American cities use De Laval centrifugal pumps. Their design and manufacture are the result of more than 57 years of experience. Units ranging up to 100 million gallons per day are available to meet all water works requirements.

Write for your copies of De Laval Bulletins 1004 and 1005 giving data on these pumps

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY
822 Nottingham Way, Trenton 2, New Jersey

DL-407A

For Simplicity of Installation, Operation and Maintenance, SPECIFY . . .

CAN BE MOUNTED AS A MANHOLE METER OR WELDED SADDLE

The rugged, dependable Sparling 906 represents a new concept for meter installations. The 906 meterhead assembly is mounted directly on a standard AWWA flanged "T" or flanged manhole outlet for immediate operation . . . as a Welded Saddle Meter, it's furnished with a fabricated saddle permitting the meter to be mounted easily on an existing steel pipe. Sizes 16 to 72 inches.

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Yes! ☐ We are interested in increasing our metering efficiency. Send us more information . . . no obligation, of course.

☐ Also send information on Sparling's line of Water Control Equipment.

Name .....

Company .....

Address .....

City .....Zone.....State.....

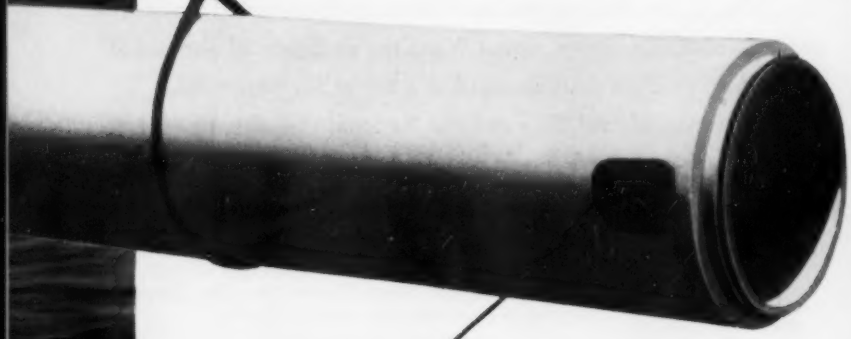
Send to: Sparling Meter Company
225 N. Temple City Blvd.
El Monte, California

The Swing IS TO

CONCRETE PRESSURE PIPE FOR RELIABLE SEWER FORCE MAINS AND OUTFALLS

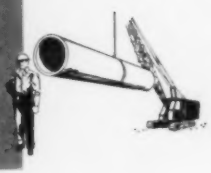
CONCRETE PRESSURE PIPE provides the ideal medium for the construction of sewer force mains and outfall lines. Dense, smooth concrete walls which defy corrosion, tuberculation and even time itself, assure a long-lasting, high-flowing, trouble-free pipeline.

In addition to low first cost, economical installation and negligible maintenance, concrete sewer force mains assure minimum pumping charges because of their inherent sustained high carrying capacity. It will pay you to consider Concrete Pressure Pipe for your installation.



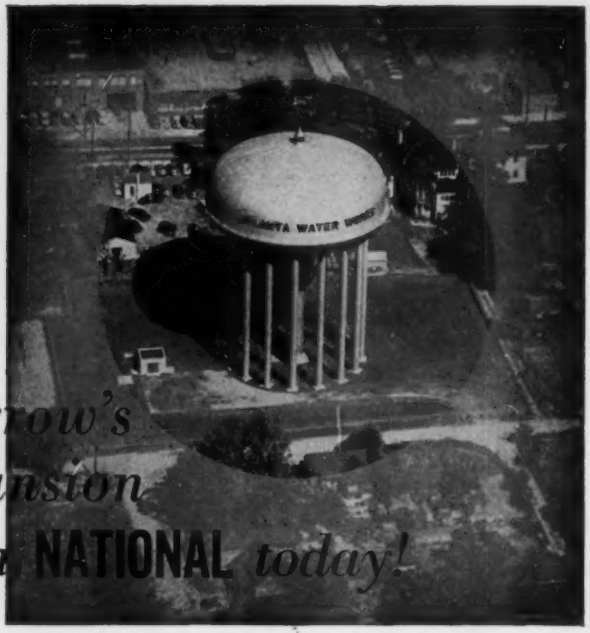
WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe



AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

228 N. LA SALLE STREET, CHICAGO 1, ILLINOIS



For tomorrow's expansion call in **NATIONAL** *today!*

Like Atlanta, Ga., *you* too can meet tomorrow's increased water demands with *clean water mains.* When the coefficient of sections of Atlanta's 45 year old main dropped to a low of 44, Waterworks General Manager, Paul Weir ordered National cleaning. Results were outstanding. Water pressure and capacity doubled, giving better fire protection and higher water pressure to outlying sections.

Do as other leading cities have done—let *National* cleaning provide for tomorrow's expansion without capital expenditure today! We can prove that National cleaning is an investment—not an expense.

Write us today!

NATIONAL WATER MAIN CLEANING COMPANY

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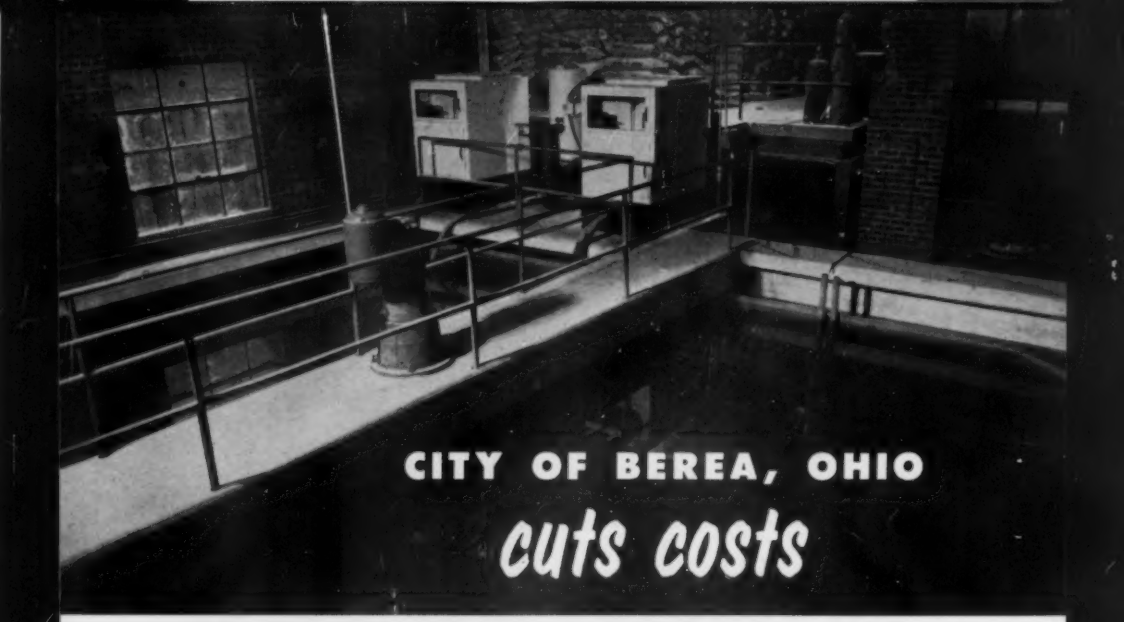
333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn., 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue, Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Marafl., Lima, Peru



CITY OF BEREA, OHIO *cuts costs*

New Cochrane SOLIDS-CONTACT REACTOR *combines*

mixing, precipitation, sludge concentration, clarification & softening

The relatively hard, turbid Rocky River supply for the city of Berea, Ohio, is quickly reduced in hardness to approximately 3.5 gr/gal and to a turbidity of less than 10 ppm by the Cochrane Solids-Contact Reactor shown above. An existing concrete basin 28′ square x 15′ deep was modernized by conversion to the Solids-Contact type. Using hydrated lime, soda ash and alum, the Reactor treats over 2,000,000 gpd at surprisingly low cost.

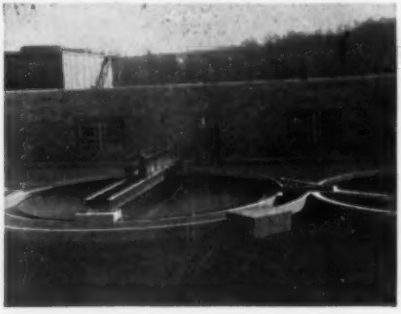
Because the design of the Cochrane Reactor provides higher quality treated water faster, in less space, with minimum chemicals, their use has grown tremendously for municipal applications. High slurry strength in the reaction zone speeds precipitation—there is very little waste water. Automatic desludging saves time and labor. In addition to softening and clarification, Cochrane Reactors remove color, taste, odor; reduce alkalinity, silica, fluorides, etc.

Cochrane's background in water conditioning makes possible the installation of complete systems under a single responsibility for continued, consistent performance. Write for Publication 5001-A and case history reprints.

Cochrane
CORPORATION
3124 N. 17TH STREET, PHILADELPHIA 32, PA.
NEW YORK • PHILADELPHIA • CHICAGO

Representatives in 30 principal cities in U.S.; Toronto, Canada, Paris, France; Mexico City, Mexico; La Spezia, Italy; Havana, Cuba; Caracas, Venezuela; San Juan, Puerto Rico; Honolulu, Hawaii; Malmo, Sweden; Santiago, Chile. **Pottstown Metal Products Division**—Custom built carbon steel and alloy products.

Cochrane also manufactures circular reactors



Demineralizers • Hot Process Softeners • Hot Zeolite Softeners • Dealkalizers • Reactors
Deaerators • Continuous Blowoff • Condensate Return Systems • Specialties

permanent

CAST IRON PRESSURE PIPE

Lowest in Long Run Costs

FOR WATER AND SEWER MAINS

This section of cast iron pipe laid in Lynchburg, Va., in the late 1820's and uncovered more than a century later in 1936, was still usable.

WHEN you specify the pipe for water works or sewer main improvements or extensions in your community, consider these facts:

First—**cost of the pipe on your job will be a minor part of the total outlay, regardless of what pipe material you use.**

Second—**differential in the cost of permanent Cast Iron Pipe and non-metallic substitutes will be negligible in relation to the overall cost of the project.**

Third—**the amortized cost of Cast Iron Pipe over its period of useful, trouble-free service—100 years or more—will be far less than that of any other pipe that you can buy at any price.**

Save money for your taxpayers! Save replacement and repairs! Specify the *only* pipe that's stood the test of time—permanent CAST IRON.

Our Company does not manufacture pipe but has long supplied the nation's leading cast iron pipe producers with quality iron from which quality pipe is made.

WOODWARD IRON COMPANY

Since 1882

WOODWARD, ALABAMA

AMERICAN METERS

HAVE WHAT THE WATER SUPERINTENDENT WANTS

ACCURACY UNSURPASSED

American Solid Casing Meter

- **THICK DISC**
- **PRECISION MANUFACTURE**

AMERICAN METERS are designed for accuracy; accuracy that resists changes caused by wear; accuracy that assures a full return for water delivered — even after many years of Service.

The reason for this accuracy record is the thicker measuring disc used exclusively in AMERICAN METERS. Increased thickness reduces slippage between disc and measuring chamber wall and the seal is maintained in any position of the disc.

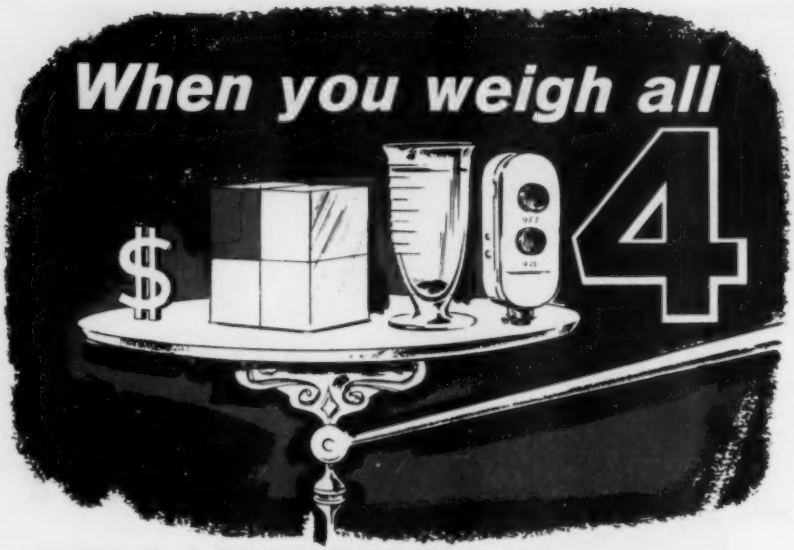
Precision machining of all parts reduces friction and wear for continued measuring accuracy.

Yes, tests prove, AMERICAN METERS have the high degree of Accuracy Water Superintendents want!

The thick disc in AMERICAN METERS makes a more efficient seal against slippage than a thin disc with the same clearance.

BUFFALO METER COMPANY
INCORPORATED

2914 Main Street
Buffalo 14, New York



...the balance swings to diatomite filtration for municipal water supply.

LOWER CAPITAL INVESTMENT

Even on a favorable basis, a rapid sand filter system will cost from 35% to 50% more than a modern diatomite system of equal capacity.

LOWER SPACE REQUIREMENTS

The space differential between rapid sand and diatomite systems is at least 4 to 1 in favor of diatomite. It may run much higher.

BRILLIANT CLARITY

Easily maintained by varying filteraid dosage to meet varying turbidities in the raw water, without recourse to the uncertain effects of chemical pretreatment, sedimentation and flocculation.

EASE OF OPERATION

Today's modern diatomite filter systems are easily and safely operated by any responsible municipal employee. Largely automatic or semi-automatic in operation, such a diatomite system requires little supervision. Applicable labor costs are low, and no highly-skilled technical personnel are needed.

These facts have been amply proved in the many municipal filtration systems now in operation, many of whom depend on Dicalite Filteraids to deliver pure drinking water to their communities.

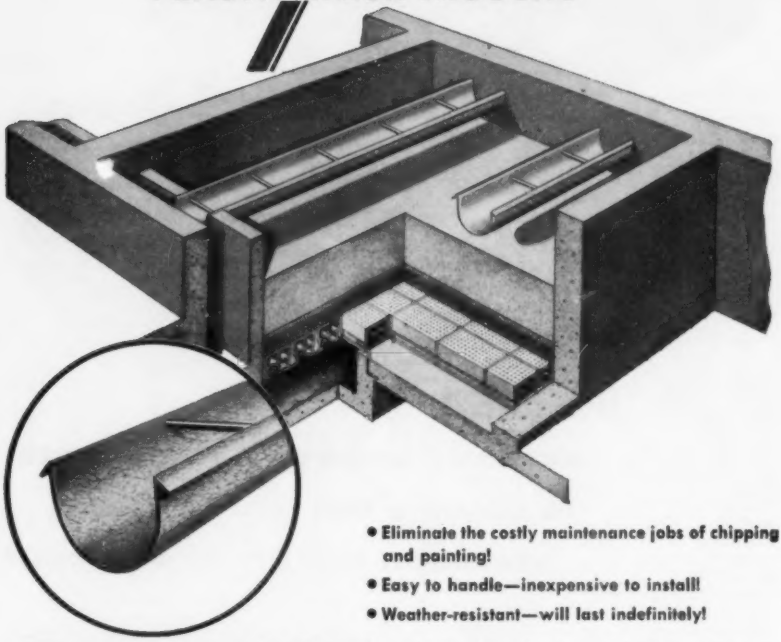
For more complete information on the use of Dicalite Filteraids in municipal water supply, write for our Bulletin BW-13.

Dependable GLC GREAT LAKES Dicalite® DIATOMACEOUS MATERIALS

DICALITE DEPARTMENT, Great Lakes Carbon Corp., 612 So. Flower St., Los Angeles 17, Calif.

Leopold

FIBERGLASS-REINFORCED PLASTIC WASH TROUGHS



- **Eliminate the costly maintenance jobs of chipping and painting!**
- **Easy to handle—inexpensive to install!**
- **Weather-resistant—will last indefinitely!**

With a background of more than 30 years' experience in wash trough design, Leopold has now developed a trough of Fiberglass-Reinforced Polyester-Laminate Plastic—a material that is structurally ideal for wash water troughs.

This new design offers a combination of advantages provided by no other type—uniform strength, dimensional stability, light weight for easy handling, complete resistance to weather and corrosion, built-in sand stop, mold-formed weir edges, and reinforced construction. In addition, Leopold Plastic Troughs, made from extra heavy fiberglass mat, are very durable—will last for years without any painting or other maintenance.

And of particular note—these unique troughs are available in a variety of cross-sectional dimensions, providing capacities to suit individual requirements.

Mail Coupon for Literature —Complete Details

Exclusive Canadian Representative:
W. J. Westaway, Ltd., Hamilton, Ontario

F. B. Leopold Co., Inc.
Zelienople, Pa.

Please send literature on Leopold Fiberglass-Reinforced Plastic Wash Troughs.

Name_____

Address_____

City_____ Zone_____ State_____

FOR ALUM

liquid or dry

the shortest

distance between two points

is usually the distance

between our plant and you!

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Monroe, La.
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San Francisco (Port Chicago), Calif.
Savannah, Ga.
Tacoma, Wash.
Vancouver, Wash.
Wisconsin Rapids, Wis.

Check the list of General Chemical's dry or liquid alum producing locations at left. Chances are one is convenient and close to you. In addition to these plants, our chain of warehouses across the country makes stocks of dry aluminum sulfate readily available in every major center of commerce. Write or phone for information on how we can serve you.

Basic Chemicals for American Industry

GENERAL CHEMICAL DIVISION

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Absolute Rigidity Means

. . . longer tool life

. . . perfect connections

Rigidity on the main . . .

Widely spread chain hook washers of the new B-100 are deeply recessed in yoke—cannot slip off when used on large diameter pipe. Unique design of chain hook keeps chain from twisting while tightening. They all add up to absolute rigidity on the main—machine cannot move during drilling, tapping or inserting operations. Broken tools and leaky connections are eliminated.

Rigidity in the boring bar . . .

Three widely spaced boring bar bearings, two in the feed sleeve and one at extreme bottom of boring bar, assure perfect boring bar alignment. Molded nylon lower bearing supports drill when it first contacts the main. Pipe curvature cannot deflect drill—tools give longer effective life. These three boring bar bearings guarantee perfect centering of tool and stop, assuring a pressure-tight connection.

MUELLER® B-100 Machine

These are only a few of the many advanced features of the new Mueller B-100 Drilling, Tapping and Inserting Machine. They are typical, however, of the attention to detail in research, design and engineering that become a part of every Mueller product used by the water industry.

MUELLER CO. MUELLER CO. Since 1857 SERVING the Water and Gas Industries QUALITY **DECATUR, ILL.**

Factories at: Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario.

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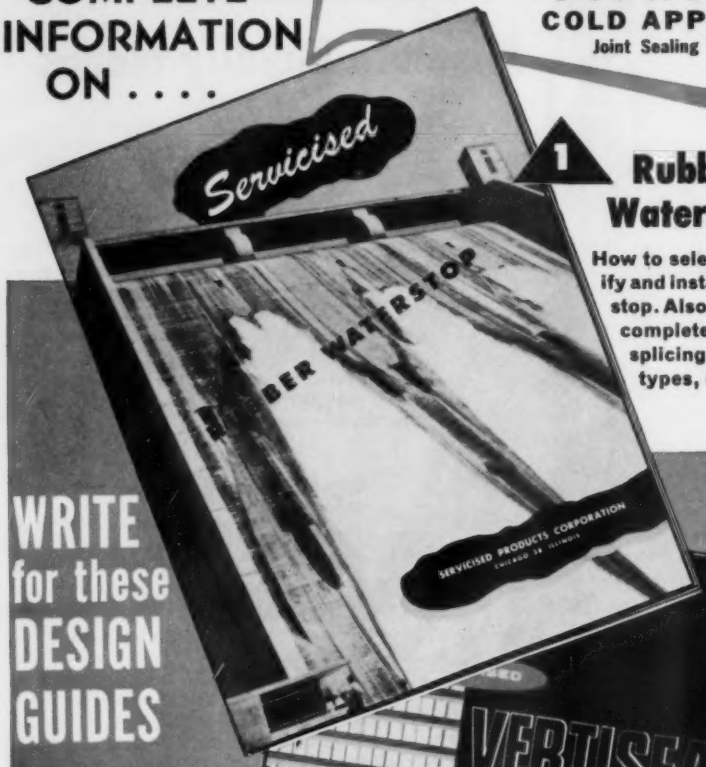
Rubber Waterstop and Vertiseal COLD APPLIED Joint Sealing Compound ?



1 Rubber Waterstop

How to select, specify and install waterstop. Also contains complete data on splicing, special types, etc.

WRITE for these DESIGN GUIDES

2 Vertiseal Joint Sealing Compound

Just published . . . complete data on Vertiseal Cold Applied Joint Sealing Compound . . . includes uses, application and instructions.

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Principles of Effective Labor Negotiation

Herbert O. Hartung and Frank E. Dolson

A paper presented as part of a panel discussion on Nov. 6, 1958, at the Seventh Annual Water Works Management Short Course, Univ. of Illinois, Urbana, Ill., by Herbert O. Hartung, Vice-Pres. & Mgr. of Production, and Frank E. Dolson, Vice-Pres., Distribution; both of St. Louis County Water Co., St. Louis, Mo.

IT is self-evident that good labor–management relations are beneficial to a healthy business enterprise. When they face each other across the bargaining table, both the labor union and management have the practical objective of reaching a signed agreement; idealistically, they have at least two parallel interests.

First, both the labor union and management have a common interest in ensuring that labor receives fair compensation for its productivity, that the importance of the individual is not overlooked, that jobs are as stable as the economy allows, and that working conditions are safe and reasonable. These interests are fundamental, for only by their proper consideration can a labor union hold its membership and the utility compete in the labor market.

Second, both the labor union and management have a parallel interest in assuring that the utility operations remain efficient, that service is good, that customers are treated with courtesy and consideration, and that the business tools are used with respect.

Mutual Interests

Although proper utility operations are the responsibility of management, it is obvious that the welfare of the employee is inextricably interwoven with the welfare of the utility. It is axiomatic that only the financially sound utility can offer security and proper compensation to its employees. Thus the labor union must be interested in contributing to the sound operation of the utility.

When both union and management negotiating teams properly recognize these important common interests, contract agreements are easier to reach. The beginning negotiation approach of both teams should be to establish, if possible, a common-interest climate.

This is sometimes made possible by a candid, general discussion of utility operations and what is fair and proper for the customer, the employee, and the utility owner. The proper negotiating climate has not been established when either the union or the company insists on labor compensation that is inconsistent (high or low) with productivity or on pay for not working, working conditions detrimental to health and family welfare, or working conditions which are not consistent with interests of the customer. The negotiating conference must recognize that both labor and management are harmed unless the interests of both are served.

Bargaining Climate

Even though the labor union and the utility management may agree on a common-interest philosophy, there may still be a wide area of difference as to what is proper and fair, but such differences can then usually be discussed without rancor and bitterness. Within the proper climate, labor negotiations are a matter of "selling" viewpoints and of compromising in order to accomplish mutual-interest goals.

Unfortunately, labor contract negotiations are not always undertaken in the interest of what is fair and proper. Too often the climate is characterized by the attitude, "How can we get ahead of the other fellow?" or, "What can we win that will give the other side trouble?" When this happens, the negotiators must adjust realistically to this attitude and utilize all the negotiating ingenuity and skill at their command to reach an equitable agreement.

It should be readily apparent that negotiators need to know as much as possible about the persons sitting across the table. Many of the matters that labor negotiating teams insist upon as important contract matters are merely reflections of the interests and attitude of a dominant member and not necessarily of importance to the entire union membership. For example, if a militant and aggressive truck driver were dominant on the labor team, much of the contract negotiation sessions might be spent in discussion of truck driving. His actual or alleged problems would have to be dealt with before progress could be made toward a contract conclusion.

Often the interest of each member of the labor negotiating team is limited to a work classification or a department in the utility. Such an individual member may have little interest in other phases of the negotiations, but he must be given an opportunity to discuss his problems and have them considered before it is possible to commence meaningful negotiations. At first glance, this approach appears to be a waste of time. Nevertheless, it is a necessary preliminary to the serious stage of discussion.

For the sake of favorable long-term labor relations, the utility negotiator should not overlook the interests of a quiet, apparently meek and passive, labor team member. The reticence of the latter does not necessarily indicate approval of working conditions or good relations with his employer. Such a person, outside of the negotiating room, can easily be the instigator of grievances and departmental unrest. By dealing properly with this type of person, and by finding out his opinions during negotiations, trouble spots may be uncovered and corrected.

The most difficult kind of person to negotiate with is the one who expounds some fallacious economic dogma and can see no relation between wages and productivity, fringe benefits and the cost of providing them, and further cares nothing about the responsibility of the utility to its customers. To break a stalemate caused by such an unbending and uninformed attitude, the help of a national union representative, business agent, or professional negotiator is often invaluable. These men can sometimes paint a more true-to-life picture to a union negotiating team than any other party. Their methods are sometimes not wholly agreeable to management, but the end results are often helpful.

There seems to be a growing number of mature and responsible men being selected for union representation before management. Some of them are aggressively and militantly in pursuit of objectives that cause management to explore and analyze operation, working relations, and procedures; others are bold, imaginative, and receptive to unusual ideas, such as an incentive plan that raises the hourly wage and at the same time lowers the unit production cost or extension of sick leave benefits by sacrificing the first 8 hr of sick leave pay. This kind of union leadership is encouraging from the viewpoints of both labor and management. It enhances job security and utility strength. It behooves the management team to recognize and encourage such personalities, even when there are differences, for they are the men who are most respected by the people they represent, and it is through them that labor and management can be cemented into the team that they should be. It is the long-term labor relations that are important.

Importance of Listening

One strategy at the negotiating table, which is equally available to both sides, is the art of careful listening. Too often negotiations are conducted in an atmosphere in which neither side is willing to listen carefully to the other. Listening and trying to understand the reasons and arguments in favor of a proposal enable a negotiator to place the proposal in its proper perspective with all the other factors of the labor–management relationship. The skilled negotiator will look for merit in the arguments offered by the other side, and, if the circumstances warrant it, he may even look for other facts that may have been overlooked. With such an attitude he is in the strongest possible position to be effective in suggesting ways by which compromises leading to agreements can be reached.

Because labor's demands are generally the dominant subject of any negotiating session, members of the management team are often forced to take a defensive role. Fortunately, this is not a weak position, and it can often be used to advantage. The experienced negotiator uses his defensive position to establish an atmosphere of reasonableness. He lets the other side talk, and interrupts only for the purpose of clarification or to oppose with reasonable arguments. He abstains from dramatic demonstrations and provocative language. By speaking in a natural voice and conducting himself with circumspection, he may encourage a business-like discussion of the issues

at hand. Above all, he never makes threats, which are a form of bluffing and an indication of weakness and deprive him of flexibility by chaining him to a fixed argumentative position.

Clarification of Issues

The usual pattern of negotiations for the labor team is to list in its demands almost anything that any member thinks might be beneficial. The strategy is twofold; first, labor apparently believes it has everything to gain and nothing to lose by aiming high, and, second, that, in order to appear to bargain, it must have some demands that it can give up without losing any of the provisions it considers essential to a good contract. Because of this procedure, the first list of demand items is likely to include many provisions that need not be considered seriously—for example, a holiday with pay on a man's birthday, paid transportation to and from lunch, on-the-job clothes for all employees, or pay for the union member who acts as business agent. (It should be pointed out that many of labor's demands that seemed extreme 10 years ago are in labor contracts today, such as funeral time off with pay, life insurance, and 4 weeks vacation.)

Early in discussions with the union negotiating team, the management team must distinguish between the various requests made, grouping them as to serious proposals and frivolous ones. The latter are easily discerned and the time spent in disposing of them could often be profitably used in establishing a climate for discussion of the important requests. The serious proposals should then be further classified as to solid-front items, small-group items, and union prestige items. Wages, fringe benefits, grievance machinery, and seniority generally are solid-front items. Small-group items usually consist of wage inequities or special working conditions, such as standby pay for construction workers on inclement-weather days. Some form of union security, dues checkoff, or outside-contractor provisions are examples of union prestige items.

The technique for learning the union's position depends upon the negotiators. Sometimes a proposal can be examined by asking how it would apply to a specific example. The union may be requested to reduce the proposal to a clause that could be put into the contract, and this may cause them to reconsider. A diametrically opposite proposal may be offered to the union at the same time its own proposal is being discussed. Often, by inviting the union to explain its reasons for the requested change, the union may reveal objectives otherwise not apparent. In some instances, the proposal may be examined by comparing it with similar or opposite provisions in other union contracts. It is always wise, even though not always helpful, to consider the effect of a proposal on the utility's responsibility to its customers.

Climax Bargaining

Climax bargaining is the most serious phase of negotiation. It is the time when the frivolous items have been eliminated and the genuine issues are at stake; each team appraises the strength of the other and estimates its maximum and minimum positions. It is also the time when each group must determine the extent to which it will compromise to avoid a strike or arbitration.

At this stage in the proceedings each side will bargain from its maximum

position of strength. A utility union may point out that its members are required to work in all types of weather, that many of them are subject to emergency call, and that they have surrendered their right to strike during the term of a contract in favor of compulsory arbitration to protect the interest of the customer. For these and other reasons, the union will insist on better wages and working conditions than those generally found in industry. On the other hand, utility management can stress such points as employment stability, long seniority, liberal fringe benefits, and opportunities for advancement.

When the climactic stage of negotiations has been reached, it is usual to determine the cost of those issues still on the bargaining table. The union needs to know the size of the package it is requesting in cents per hour. Management also needs this information and, in addition, must know the total amount in dollars so that it can be related to operating costs. Unit cost figures will often reveal that certain requests will benefit only a few at the expense of the many, for all such costs are properly chargeable to the total package. Some items may be difficult to price owing to limited past experience or because only a few people are immediately involved. Nevertheless, the cost of such items should be appraised realistically and taken into consideration when the wage package is made up.

The techniques of climax bargaining are many and varied. There is no way to reduce the procedures to a convenient formula for getting each side to sign an agreement.

When the union, by direction of its members, is unyielding on an issue, and management, for reasons it believes are important, is adamant in its position on the same issue, a proposal that allows both teams to hold to their respective positions (sometimes called a "gimmick") will often break the deadlock. For example, management may find, in the interest of the customer, that it is necessary to rearrange the work schedule for certain employees from the usual Monday-through-Friday period to Tuesday through Saturday. Union negotiators may say that any package that includes such a provision simply cannot be sold to the union membership, and that they therefore cannot agree. A solution to this problem is to write the provision into the agreement, but in such a way that the working condition applies only to employees bidding for the job.

Another example of the use of a "gimmick" is to grant increased sick leave, on the condition that the union share increased cost to some extent by giving up the first 4–8 hr of sick-leave pay. Still another example of this useful negotiating tool is to agree to pay ½ hr per day at the overtime rate during the first 30 days when an employee is reassigned to another point for starting work.

Sign Language

It is not unusual for negotiators to resort to the use of a sort of sign language to convey offers and counter-offers. By using this technique, labor or management may reveal agreement possibilities without making definite commitments. For example, a counter-offer that cancels out the original demand may be used to tell the other side that they must first be realistic if serious counter-proposals are to be expected. Another example of this technique would be an apparently adamant position on a minimum acceptable

wage package that is supported by data contain an obviously weakening error. This may be tantamount to saying that the wage package suggested, corrected for the obvious error, is the actual minimum acceptable amount.

Communication by the use of signals is employed at almost every bargaining table, even though principals often fail to realize that they are using the technique. For this reason, the experienced negotiator is extremely wary of attaching too much significance to this type of communication unless he has reason to believe his counterpart fully understands the language.

One Additional Fringe

Probably the most vexing bargaining tactic that a negotiator can encounter is the assertion that an acceptable package must be more than the last offer. Sometimes this strategem is described as the policy of "1 cent more per hour" or "one additional fringe." Although this method of bargaining may be effective once or twice, the long-range effect is not beneficial, for the other team quickly reacts by being extremely conservative in any future offers. Here again, the professional union negotiator can be helpful. He knows from experience that such tactics are of only transient value, and that in the long run they may be detrimental to the union's best interest.

Good-faith bargaining has often been described as bargaining entered into with the sincere purpose of reaching an agreement. When both labor and management sincerely follow this doctrine and never lose sight of the fact that they have a common interest in one another's welfare, differences can usually be resolved and contract agreements can usually be reached.

Organization of a Master Disaster Plan

Jeptha A. Wade Jr.

A paper presented on Oct. 31, 1958, at the California Section Meeting, Los Angeles, Calif., by Jeptha A. Wade Jr., Assist. to the President, California Water Service Co., San Jose, Calif.

IN recent years, the American public has become increasingly aware that it would be a target in the unfortunate event of another major war. This uneasiness has, in turn, been communicated to the representatives in government, where there has been a significant lack of ability to instigate plans that are either practicable or realistic for the ordinary operating problems that each person or industry would experience. This is, after all, not surprising, because any such planning would have to be of a tremendous magnitude and would require specialized knowledge of individual problems. The costs of such a program would be enormous. In the event of disaster, each one will be initially left to his own devices.

If a water utility is to function immediately after a disaster and thereby be permitted to continue to control its own operations, it must obviously take the first step itself and develop a plan. Such a plan, if well thought out, will be applicable to a major atomic or hydrogen attack, if it comes, and to the more limited natural disasters which are sometimes inevitable.

Within recent years, the California Water Service Co. (CWSC) has experienced such natural disasters as the Tehachapi earthquake and its aftershocks, which hit Bakersfield in the summer of 1952, and natural floods in Visalia in February 1945 and in Marysville in December 1955. Over the years, these experiences have made it necessary to develop plans, which, it is felt, will now go a long way towards helping the CWSC to survive the initial shock of any disaster.

Some of these plans and experiences will be described here in the hope that they may prove useful to others and encourage those who have not done so already to develop similar plans tailored to their own operations.

Local Operations Plan

CWSC's past operating experiences have resulted in a simple master disaster plan, which is widely distributed and immediately available at all levels of the company. By way of background, it should be mentioned that the company consists of nineteen integral units or districts located throughout the state, from Redondo Beach in the south to Chico in the north. These systems serve communities of various sizes. For instance, the company serves 3,300 people in Dixon and 116,000 in Stockton, with a total of some 231,000 accounts serving an estimated population of 840,000.

CWSC maintains its corporate headquarters in San Jose, including its engineering department, materials control, and general accounting functions. The company structure permits the maintenance of a high-calibre manage-

ment team, which serves the needs of 840,000 people and is available to all operations alike. This organization has many advantages in ordinary operations but it also has certain deficiencies which must be compensated for in the event of a disaster. On the positive side, because it is unlikely that all operations would be affected to the same degree in the event of a disaster, the entire strength of the team could be focused on any particular trouble spot.

Concentration of Authority

One of the difficulties encountered in any organization of medium size is that major deviations from ordinary routine usually have to be referred to higher levels of management for decision; in the event of a disaster, this refinement may not be possible. First, because of the time required, and second, because of a probable restriction in communication, it is necessary to establish a clear-cut line of authority that is operable on the lowest levels so that the organization can begin to function as quickly as possible following an unexpected interruption in routine operations.

After centuries of experience, military organizations have established a highly refined line of command; for any set of circumstances the ranking senior is in unquestioned command. A military line of command does not ordinarily form the most flexible and desirable system for ordinary operation, however. Under ordinary conditions, the responsibility for decision may be spread among many people, and operating decisions are quite often made on a staff basis without real line-of-command authority. CWSC has compensated for this by instituting in its master disaster plan an established pattern of operation, which indicates in black and white who are the direct alternates to the nominal local authority. This is important because the manager or superintendent may not be available owing to injury.

After the local authority has been established, the next few steps of the disaster plan are perhaps the most important to its successful implementation. It has been found by observation of other successful plans and through direct experience that, once the person of responsibility has been selected, that person must be available at all times for decisions. The plan calls for establishment of a headquarters and requires that the person assuming the responsibility on a local level go immediately to the headquarters and stay there. In this way, everyone knows where to look for him. The natural reaction of most people in emergencies is to rush about quickly and satisfy their personal curiosity by direct personal observation. Such action greatly reduces the effectiveness of the entire crew. The chief authority must not leave the operational headquarters to observe field conditions during the initial stages, but must base his conclusions upon the observations of others who report to him. Only in this way can sufficient balance be maintained to marshal forces to the most pressing needs.

Damage Survey

After the establishment of an operational headquarters and determination of the person in authority, the first item of business is to make a survey of the disaster. All available personnel, with the exception of the chief, are immediately dispatched to cover individual

sectors of the community. Their instructions are not to stop to make any repairs, to survey the situation quickly, and to bring this information back to headquarters as soon as possible. In this way forces may be dispatched to the more pressing problems first, according to a logical sequence of priorities. What may seem to one person to be disastrous in any particular sector may be very much less important by comparison with damage in other sectors. The decision should be made at headquarters, and made as soon as possible. The person in authority should dispatch his personnel where they will do the most good, not simply to those problems which are first apparent.

Isolation of Damage

The second step, after observation of the degree of damage, is to cut off and isolate the damaged portions of the system before making repairs, so that the maximum uninjured part remains operable and the greatest possible saving of storage reserves can be made. At this point, it becomes necessary to establish communications with others. Information must be provided to the fire department as to those areas where the availability of water may be curtailed. The health departments, police department, and others must be made aware of the situation. It is important that the person in authority very quickly designate only one person in his organization to channel this information to the other agencies. During an emergency, rumors and misinformation may be the most dangerous problems to overcome. If information as to the extent of damage and the steps that are to be taken is disseminated from more than one source, confusion is bound to occur. When there are resources available, this information should be accurately transmitted to the proper authorities and if any curtailment of service is required the precise extent of curtailment should be decided by the proper people. If public announcements are required for press or radio the information must be accurate.

These then are the first four steps that must be taken in the event of a disaster: [1[decide as quickly as possible who is to be in charge; [2] establish headquarters; [3] once authority and headquarters have been established, make a survey of the damage before taking any corrective action and isolate the damaged areas to preserve storage resources, and [4[get accurate information of the situation to all of the other interested agencies. In addition to these things it is vital to establish contact with the rest of the utility organization—which suggests the next area of planning.

Communication

During periods of extreme emergency, communication is vital to the economical use of available forces. For CWSC, this means communication throughout the state. Materials are kept in stock at each of the CWSC plants, and equipment and personnel are available for transfer from distant areas into a trouble area, as are the engineering and management teams. Unfortunately, it is during an emergency that the ordinary lines of communication are most likely to become overloaded and break down. In the first place, physical damage will interfere with communication lines just as it does with other utilities. For this reason alone, it is highly desirable to develop radio communication, which can

be independent of the established routes. As a matter of operating convenience, a number of years ago CWSC installed its first radio communication equipment. As with everything else, this program has developed gradually. The first hesitant steps were taken shortly after the war, when the telephone company brought out mobile telephones which could be installed in automobiles and were tied directly into the telephone system. This served the purpose originally, and units were installed in the cars of traveling superintendents. As the popularity of these units increased, however, and traffic on the radio became greater, it was found that the usefulness of this type of communication was limited and equipment was purchased that would operate on a semiprivate utility frequency. Originally this equipment was used only for contact between the principal supervisors and a base station.

As the equipment became more familiar, however, the use of radio equipment was extended to the regular operating crews until today 22 fixed stations are operated and over 50 mobile units. In addition, other mobile units are maintained on this frequency in certain of the vehicles operated by the company's contractors.

Following the Bakersfield earthquake standardized equipment was installed in all CWSC districts on the same frequency in order to construct an emergency network that would permit communication throughout most of the districts by relaying messages from point to point. Of course, the high-frequency radio equipment that is standard for this service is quite limited in its normal range. Under ordinary conditions it has a range of 8–20 mi—subject to freak conditions, which may extend reception all the way across the country. This limited range is quite closely related to the efficiency of the antenna used. The regular installation includes a base station with a high antenna, but the mobile units installed in CWSC vehicles have only whip-type antennas, which materially limit their range. Many of the base stations broadcast from units in one city to other cities in which the company operates. If point-to-point contact cannot be established between operating districts, because of distance or intervening mountains, there are two alternatives. Mobile equipment can be dispatched to set up one or more message relay stations between the bases, or a single mobile unit can be driven to a point where it can establish communication with the base station in the middle of the disaster area and relay information by telephone from that point. Ordinary telephone communication would probably not be too greatly overburdened at some reasonable perimeter distance from a disaster area. One caution should be observed, however. FCC license permits for this class of service do not allow point-to-point communication on an ordinary basis, even though such communication is legal in the event of an emergency.

Standby Provisions

The CWSC base stations are powered by the ordinary electric service. When the author inquired as to what provision had been made for standby power in the event of a power failure, he was surprised to learn from the engineers that the radiating power of the mobile unit is similar to that of the base stations. If there should be a power failure, arrangements have

been made to plug a mobile unit into the base station antenna and thereby take advantage of the base station's greater range by using the mobile power facilities of the vehicle. This is a very simple procedure and insures that the standby units, as they are regular operating units, are being continuously maintained. As another link in this chain, two mobile radio units are also maintained in the statewide traveling superintendent's car. The first is hooked into the company system and the second is tied into the standard telephone company system. Incidentally, the water company now leases all its radio equipment. It is felt that even where there is a limited number of units, they are assured of proper servicing. In addition to the mobile units and base stations, there are several walkie-talkie or field communication units operating on the company frequency and powered in the field by rechargeable storage batteries or, when available, the ordinary 110-v, 60-cycle current. This unit supplements the other units very nicely and permits the establishment of temporary headquarters at any place.

Other Lines of Communication

There are many other means of communication that are also available if a little forethought is used. Much of the equipment referred to above is regularly available on all levels during ordinary working hours, but is not necessarily operating at all times. The first message out of a disaster area might well be the most difficult to get through. Once the undamaged areas outside the disaster area were aware of the existence of a disaster, all forces could start in motion, but many precious hours might be lost if it were necessary to depend on the ordinary channels. Experience has shown that "ham" radio operators are very useful in getting out messages in such a situation. CWSC has used their services in the past and has issued written instruction to each of the districts to establish communication with these devoted amateurs in advance of necessity. As many of these operators are young, lists must constantly be reviewed to make sure that the operator is available. Other utilities, such as the power companies and railroads, also have private communication systems. The highway patrol has a statewide radio system and, of course, the local civil defense offices have made a major project out of establishing a statewide communication system. Of course, the telephone company would be flooded with calls in a major catastrophe, but they have established, with the help of federal legislation, a system of priority, which gives a high priority to utility calls. By contacting the telephone company supervisor and identifying the utility activity and the necessity for priority, a utility will be accorded maximum consideration in the placing of long-distance calls. CWSC also maintains a statewide message center on a 24-hr, 7-day-a-week basis. This center is equipped with radio contact to the utility system and, of course, is tied into the telephone circuits. The message center acts as a clearing-house for tracing throughout the state supervisory personnel who maintain contact with the center when they are out of town and away from their regular telephones.

Preservation of Tools

Another area of operation which must be considered in developing an

orderly disaster plan is the preservation of tools, which breaks down into two categories. First, the physical repair tools and materials, including chemicals; and second, records and maps. Each basic operating unit must obviously maintain a stock of replacement parts and chemicals just for ordinary operations. It is important, however, that management give serious study to the basic operations of the system which might be damaged and stock replacements for key units that are not carried in routine stock and could not readily be improvised in the event of disaster. Of course, there is no need to plan on complete operation of the system, but it should be seen that loss of a few elements would not so completely disrupt the system that there could be complete failure. An important corollary to this program is adequate, well distributed records that show at a glance what is to be maintained in emergency stock and where it is stored.

During a California flood, wells had been removed from the system and shut down in areas threatened by rising water. It was necessary to disinfect these wells to eliminate any hazard of contamination before returning the units to the system and to raise the chlorine residual throughout the distribution system as an additional safety precaution. As a result, the local stocks of chlorine were considerably strained. Much time and effort were spent in locating other supplies in the middle of the night and distributing material 100 mi to the flooded area. Of course, it was somewhat difficult to accomplish this in the middle of the night, but the arrangements were finally completed, and, in due course, the new supplies were in transit to the scene. During the coffee break that followed, and after a little reflection, someone asked the foreman whether he did not maintain an extra supply of chlorine. "Oh, yes," was the reply, "we have that." When asked why he had not used it instead of going all over the state to get a new supply brought in, he gave the obvious answer: "Oh, our instructions are to save that for an emergency."

The importance of having a written plan cannot be overemphasized. No matter how well thought out in advance, the plan must be available at every level when it is needed. CWSC's basic plan is reproduced and placed in each of the vehicles, along with self-sticking signs, which can be fastened to the car doors and identify the unit as an emergency vehicle for public water supply. The plan must be simple. It does no good to hand someone a thick book during an emergency; a couple of sheets of paper with some answers on them may be used. What is needed is a simple key to indicate where to look for the things that have been so carefully accumulated and to indicate emergency procedures that have been developed in advance. It does no good to plan in advance unless the plans are used. In setting up an emergency stock of materials it is vital to let everyone clearly understand its purpose. It is possible, otherwise, that when the emergency items are needed, it will be found that the accounting department has ordered the elimination of those items of stock that showed no activity.

Preservation of Records

The preservation of records and maps is also important. With the items of destruction available today, prudence indicates the absolute necessity of making some provision for stor-

age of basic records. The cost of such a program is so infinitesimal compared to the cost of reestablishing records that management can hardly justify the risk of not making provision for storage of basic duplicates.

There are a few principles which should be used as a guide in determining which records to preserve. The first is their importance to immediate operations, another is the intrinsic value of the records themselves (by this is meant the cost of preparation), and another is the value of the records for establishing ownership of other items. Maps and records of underground installations certainly qualify in all three categories. One problem, however, is the decision as to how maps are to be stored. Microfilm is certainly the cheapest from the storage point of view. Microfilm is not always handy for immediate use in the event the original records are destroyed, however, unless there is reproduction equipment available at the storage depository.

Many companies may find the procedure adopted by CWSC to be an economical and satisfactory solution. Full-size copies of each system map and block plot detail sheets are made each year and kept at a depository located in one of the inland cities, which has been established as an alternate disaster headquarters. Access to this vault is available on signature to a widely separated group of company executives. Copies of the layouts of the most important pumping installations are also kept there. These are thus available for immediate use and can be reproduced at leisure, if and when such reproductions are required. These records are readable and need not be processed by any further mechanical steps.

In the category of valuable CWSC records are such papers as monthly financial statements, which are filed in full size each month and kept in the depository for a period of 5 years, and important ledgers, which are microfilmed for storage at regular intervals. In another category, there are records of ownership. An example of the difficulty caused by loss of such records is the earthquake and fire in San Francisco in 1906. Even today property transfers in San Francisco and San Mateo County are sometimes hampered by the destruction in 1906 of official county records. There is a great deal of secondary preservation of property records today, however. In addition, most of the counties in California follow the practice of having official records microfilmed for safe storage, at least records of property transfers. An inventory of property deeds is probably sufficient to reestablish ownership. Each company should evaluate its own economic breaking point in the preservation of records. One must, at some point, assume a certain risk. The burden of being safe, theoretically, for a disaster should not overburden day-to-day operating efficiency.

Conclusion

The author has attempted to outline in this article the progress of one company in building a disaster plan. The discussion has been limited to the specialized internal program it has developed. The plans outlined here will not be equally applicable in all organizations. In the analysis of such a program, however, the proof of its effectiveness is in how it actually works. During the earthquake in Bakersfield major units of the water system, in-

cluding two elevated tanks, which had been built many years before with no provision for earthquake loading, and well pumps were lost without any of the customers being aware of an interruption of service. This CWSC plan has been tested and developed through such experiences. Its refinements are a synthesis of the combined efforts of a great many people.

No effort has been made in this article to discuss the next level of planning for a disaster; this is the responsibility of the state office of civil defense. The water supply industry and the members of AWWA can well be proud of the cooperative efforts that have given form and substance to the utilities division in the state civil defense office and to the California water, gas, and electric utilities joint agreement for mutual aid. Of course, any statewide plan must always depend on the individual organization for its basic operations—few would wish it otherwise.

Modern Insurance Program for Water Utilities

S. Cook Shaw

A contribution to the Journal by S. Cook Shaw, Field Repr., Insurance Audit & Inspection Co., Indianapolis, Ind.

A WELL devised, modern insurance program is essentially simple, whether it is designed for a municipally or privately owned water utility. (This applies, as a matter of fact, to any business.) During the past decade or so insurance methods and policies have been designed that are reasonably inclusive, extend the scope of coverage into fields not previously developed, and provide in one or two contracts coverage formerly requiring a dozen contracts and at a cost usually somewhat lower. Insurance costs are, in fact, far behind the inflationary spiral that has affected almost everything else. The grouping of coverages under fewer contracts not only reduces actual cost and improves protection, but also reduces the burden of administering or placing policies.

Comprehensive Coverage

A simple insurance program does not mean one devised with little thought or administered carelessly. The author has examined many fire insurance policies that would, because of the workings of the coinsurance clause, pay only about half of any loss. Windstorm losses have been denied by reputable companies because the policy provided that wind losses were not covered unless the building was fully enclosed with all windows and doors in place. This has occurred even in cases where the building was under construction and was so described in the policy—with an increased premium for that reason. A certain county in Michigan was building a new courthouse and the officials in charge were impressed by the offer of a policy covering "all risks of loss or damage." This seemed a great improvement over the fire protection and extended coverages usually purchased; the officials logically felt that there was value to coverage against collapse of the building or theft, which was included in the construction-risk policy. The officials, however, failed to read the exclusions in the contract. (As in all so-called "all-risk" policies the exclusions took up more space than the insuring clauses.) The collapse, the theft, and the wind coverages were all conditioned upon the building being fully enclosed. The officials also failed to note that glass was completely excluded in the contract; this building was a modern type which was 80 per cent glass.

The term "comprehensive" has a very reassuring sound when applied to a liability policy. The author, however, has yet to see a comprehensive liability policy that covered the risks of libel, slander, false arrest, violation of privacy, or liabilities assumed under contract without limitations unless the

insurance buyer specified and insisted on such coverage. Most comprehensive contracts provide that all hazards must be disclosed to the insurance company. Utility officials frequently do not know what information the company wants. They simply answer the questions the insurance agent asks and are unaware that their contract probably provides that the disclosure of hazards is their responsibility.

These are only a few of the gaps that might be present—even with a policy which is called "comprehensive," "all-risk," "cover-all," or any other name devised by a sales-minded underwriter. Usually the policies are good, the insurance companies are substantial, and the agents are sincere. Nevertheless, the purchaser should know exactly what his policy does and does not cover. If an exclusion is objectionable to the customer it should not be accepted; this can often be arranged by means of a very nominal increase in the premium, or even no increase.

Property Loss or Damage

A sound insurance program should cover a number of different categories. One of these categories, boiler and machinery insurance, is essential to a water utility but is too detailed and technical to be described in this article. Another of the most important categories is loss or damage to property.

Many water utilities have pumping stations which the officials correctly consider free from fire hazard. Nevertheless, these same utilities may have loan or bond-issue agreements which require the maintenance of insurance to an agreed percentage of property value. In such cases if a utility has property it feels should be self-insured it is necessary to modify the indenture or other agreement before doing so.

In most instances the buildings of a utility should qualify for very attractive board rates for fire insurance and preferred rates for wind insurance. Before granting these low rates, however, insurance companies will require a coinsurance clause which provides that the utility maintain insurance to 80 or 90 per cent of the replacement value, less reasonable depreciation allowance. This means the replacement value *at the time of the loss*—not yesterday or 20 years ago but what it would cost the day the loss occurs. Unless the utility has some reliable basis for determining this value, it cannot possibly fulfill its part of this agreement. An unreliable basis will probably result in a too-conservative estimate. As a result the utility will be penalized in a loss settlement and may find itself in a poor financial situation.

It might be well at this point to mention that insurance companies are usually fair, and perhaps even liberal, in their treatment of a policyholder. They are inclined to give him the benefit of all doubts and frequently—but not always—pay off on a basis of the intent of the contract rather than what some incompetent agent or careless clerk actually wrote into the contract. The author does not, however, recall any case where an insurance company has passed over the coinsurance requirement. (In one instance a company discovered that a policy had been ordered without the coinsurance clause but that it was later inserted by error. This entire claim was paid but perhaps the company was influenced by the fact that the loss was less than $3,000.)

The most reliable way to determine replacement value is to hire a profes-

sional appraisal engineer to do the job. In the case of a power plant of some age where depreciation presents a difficult problem or of a property of such size and complexity that it demands professional appraisal this is about the only way. A few insurance companies offer this service free on small, simple buildings. In some instances a local contractor with an adequate estimating organization can determine the replacement cost at current market prices. From such estimates the utility deducts depreciation at a conservative figure; in some instances depreciation may be worked out by a local insurance adjuster.

Equipment and supplies can be inventoried by the utility department heads; original price and depreciation can be supplied by the purchasing department. Any method is better than guesswork. If the utility does not have some reliable method of valuation that can stand the test of a court of law it will in the event of loss be in for trouble.

Insurance against fire, lightning, and the perils enumerated in the extended-coverage endorsement has become standard insurance procedure. Losses due to vandalism and malicious mischief seem to be increasing throughout the United States both in frequency and severity. Insurance against these perils is relatively cheap and in all probability should be included in a comprehensive insurance program. So-called "all-risk" policies are becoming increasingly available, particularly for tanks and in connection with floater coverages. The perils of theft, water damage, and collapse are usually included in these policies. Once again, however, it is essential for the utility to study carefully the exclusions included in any "all-risk" policy.

Every utility office has records which would be difficult and costly to replace if they were destroyed: drawings, records of water or utility bills, tax records, and many others. A standard policy would pay only for the cost of the blank paper and the cost of copying if these records were destroyed. Frequently, however, there would be nothing from which to copy and the entire data would have to be reassembled. It is better to eliminate these values from the regular fire insurance schedule and cover them under an all-risk "valuable papers" policy. Better coverage can be obtained on the papers in this way and items whose value is next to impossible to determine are eliminated from the coinsurance requirement. These valuable-papers contracts pay for the complete reconstruction of the destroyed records.

Utilities sometimes apply the principles of partial self-insurance with excess covers, which are available in several different forms. These contracts are usually individually tailored to suit the particular insured; their desirability must be judged by relating the exposure to a single loss with the amount of total premium involved. Marketing these contracts requires considerable specialized skill and relatively few insurance agents are equipped to do it successfully. Carefully devised self-insurance may be advantageous for a utility with a really large premium expense but individual cases must be studied and generalizations would be misleading.

Form and Term

In some instances the most efficient form of policy is a schedule of all items to be covered with a stated amount applying to each. In others a blanket form covering all property except spe-

cifically excluded items, such as property properly self-insured, is more efficient. These forms do not have to be in one policy but may be distributed among several companies and agents if desired. Where a division is made on the schedule basis each policy will cover its proportionate part of the entire schedule. On the blanket basis it is not usually necessary to show the total amount on each policy as each contract simply covers a stated amount on the blanketed items; under standard terms it would prorate any loss with any other policies in force on the same items.

All policies covering the same property should definitely be identical in every respect, with the possible exceptions of amount, date, and premium. These policies may be arranged to expire at the same time on straight, long-term, annual payment plans. Straight, long-term policies expiring on alternate years may also be arranged. The latter method is usually the more economical. Regardless of the terms of the policies the whole property program should be reviewed at least once a year to correct for acquisitions, dispositions, value changes, changes in available forms, and other changes.

Workmen's Compensation

Workmen's compensation insurance is designed to comply with the laws of the various states. Rates for this type of insurance are closely supervised by various state bureaus. The principal points to consider are:

1. The amount of coverage applicable to those claims which do not come under a compensation law—and there are some in every state
2. The medical payment limit* if a state restricts such payments
3. Compliance with federal law if any employees of the utility have to work with ships, boats, or other waterborne transportation
4. Coverage of employees when they are out of the state.

If premium payments for workmen's compensation insurance are a substantial item in the utility budget then self-insurance should be considered. In some instances, when cushioned by excess insurance of the proper type, it is desirable. As in the case of property loss or damage insurance this is a matter for individual study.

In connection with any insurance coverage loss history is important. In the case of workmen's compensation insurance year-to-year rates directly reflect the utility's own experience in various degrees, depending on size of premium and frequency and severity of losses.

Public Liability

Public liability insurance has become in many instances a major problem with all types of business, and especially with utilities. Many water utilities are municipally owned and are, therefore, supposedly entitled to a degree of immunity from many types of claims and proceedings. The truth is that anyone concerned with municipal insurance today knows better than to rely on this "immunity"—especially where utilities are concerned. In fact, most municipally owned utilities have a clause in their insurance contract which prevents the insurance company from using as a defense the so-called immunity unless the insured consents.

The hazards of liability from false arrest, slander, libel, violation of privacy, and similar occurrences seem to be increasing in importance every day.

Most insurance companies will cover these hazards but underwriters have different ideas on how the coverage should be worded. In the author's experience a little argument by the insured can usually get him about what he needs, if not from one company then from another.

There are several other factors to be considered in planning a public liability program. All underwriters may not find all of a utility's liability hazards desirable insurance risks. Some utilities may have hazards that no underwriter wants to insure. It therefore follows that when the insurance company designs the policy it is certainly not going to include coverage it does not wish to assume. As previously mentioned it is, by the terms of the policy, the utility's responsibility to disclose all of its hazards and points of exposure. A good, safe way to do this is to let the agent assume the responsibility of finding out all he wants to know, not with the idea of trying to cover up something but to avoid any charge of misrepresentation.

A new trend in underwriting is to have the insurance provided on a blanket basis governed by a composite rate method based on total payroll, gross receipts, number of meters, or any other factor which in the utility's judgment represent a fair measure of liability. Theoretically the same premium should result regardless of the factor used. If the factor is well chosen it can work to the utility's distinct advantage. Individual cases, however, will require some experienced help, in addition to the guidance supplied by the insurance company.

Most policies refer in their insurance clauses to death, disability, damage to property, and other losses "caused by accident." Many types of loss can occur that do not come within the legal interpretation of the word "accident." Insurance will much better serve a utility's needs if instead of covering "accidents," it covers "occurrences."

Many contracts which a utility handles in its daily operation—contracts of purchase, of sale, of service, and others—contain "hold harmless" clauses. It is true that no organization can be sure of avoiding liability by contract but on most contracts the contractor may be held harmless by reason of such liability. The regular public liability policy covers only liability "imposed by law" and only in a very limited degree will it cover liability which may have been assumed under contract. Contractual liability can be insured on a blanket basis and in most instances should be. Sometimes a certain amount of shopping among insurance companies will be necessary to do this.

A water utility will, in all probability, have certain types of earth-moving and other equipment which is automatically insured under general liability insurance. Nevertheless, in many programs these same machines are scheduled in the automobile liability policies and unnecessary premiums are paid.

All workmen's compensation and public liability insurance, including automobile liability insurance, should be purchased from the same company even if it is covered by two or three policies. There are cases where the line of demarcation between workmen's compensation, general liability, and automobile liability is very indistinct and if different insurance companies are involved real difficulties may be created. If one company has all these

coverages the argument is within the company and will in no way prejudice the policyholder.

Crime

Crime insurance involves, first of all, an honesty bond on employees. The blanket honesty bonds available today are the most practical method. The two most common types are: the blanket-position bond which applies a given amount to each employee, and the commercial-blanket bond which applies a given amount to each occurrence, regardless of the number of employees implicated. There is a difference of opinion among insurance men as to which of these is better. Both are written without listing covered employees or requiring individual applications by employees. Many insurance companies will provide an investigation service, however, if these applications are filed.

Many types of burglary, robbery, and forgery policies are available, but most of them are somewhat limited in scope. The modern "money and securities" policy covers these risks in one contract and is far superior; even better is the so-called "comprehensive crime" policy. Some companies refer to their dishonesty, disappearance, and destruction policies as comprehensive crime policies. They are simply a combination of the blanket-honesty bond and the money and securities policy. There is a comprehensive crime policy available in some states that is quite good.

Competitive Bidding

One of the most frequent questions to arise in developing an insurance program is whether to submit the insurance requirements to competitive bidding. The answer is yes and no. If this has not been done for some years it might be a good idea to consider. A city in Illinois which operated a power plant asked for plant insurance bids from the local agents in the town and from a group of large mutual companies not affiliated with the local fire rating bureau. On the first bidding the mutual companies bid about half what the local companies bid. The local agents, however, persuaded the municipality to lay all bids aside and call for new bids in 30 days. During this period the fire rating bureau reinspected and rerated the plant and, on the rebid, the local agents had the lowest bid. The municipal authorities are convinced that the open bidding was responsible for a substantial saving in their insurance costs.

There have been hundreds of similar cases. They are most common in connection with floater policies such as policies covering construction equipment, all-risk policies on tanks, and other policies of a similar nature. Competitive bidding is also helpful on crime coverage and at times is advantageous on liability insurance. On excess covers used for bolstering self-insurance or partial self-insurance plans, on the other hand, competitive bidding can be actually detrimental unless it is handled very judiciously. There is also another side to the question even in regard to types of insurance on which competition may be of value. The matter of service rendered must sometimes be considered. In a northern municipality which operated its own utilities a group of local agents, with the assistance of company engineers, worked out a reasonably good appraisal of the property owned. Regularly, once each year, these men reinspected the property and revised their figures. Fire rates were at the

same time carefully checked by company engineers and every effort was made to maintain insurance costs at a minimum. The policy form was worked out with great care and every effort was made to provide the most efficient coverage possible. These agents really earned their commissions. The author feels that the officials of this city should give full credit to the work of these public-spirited agents because the service they are rendering cannot normally be bought. This is not an isolated case by any means.

In a case which recently came to the author's attention a municipally owned utility issued bid invitations to twelve agents but received only two bids. This utility had overworked competitive bidding by putting its insurance coverage up for bids every year. The liability program of this utility had been placed with a different company every year for 5 years and in some of those years loss experience was not good. An underwriter who has a stabilized customer will frequently assist the policyholder in correcting difficulties during a bad period and will average the good years with the bad. This utility needed more stability in its insurance buying.

There is no hard and fast rule to cover competitive bidding. Sound judgment is needed. If bids are taken it should be made clear that factors other than cost will be given consideration. The utility should let it be known that it is looking for service; changes should be made with care. If a utility has never invited bids on its insurance—or, at least, not for a long time—it might be advisable to try it on a careful basis for one or two items. Surprising and gratifying results might be achieved.

Conclusion

A good loss experience is distinctly to the advantage of the utility. Any damages, even though adequately insured, still involve an economic loss of some sort. Companies which buy large amounts of insurance of many types and have an active insurance department frequently operate on the theory of first preventing all the losses possible and then developing an insurance program that will prevent great financial shock to their assets.

A final caution: an insurance policy is a contract and should be dealt with like any other contract. If a utility agrees to furnish water to a customer it would not expect also to install his plumbing. A contract of insurance should not, therefore, be expected to do more than it specifies. The insurance policy should be read and evaluated as carefully as any other contract. If a water utility official does not have the time or technical background to do this himself he should secure the services of someone who can.

Value of Reports and Budgets in Management

Jack S. Parrish

A paper presented on Oct. 1, 1958, at the Alabama-Mississippi Section Meeting, Biloxi, Miss., by Jack S. Parrish, Ala. Mgr., Management Services Div., Ernst & Ernst, Birmingham, Ala.

TO most Americans the year 1776 signifies a period of great political upheaval. In the business world, however, that year has an added significance, for in addition to the Declaration of Independence it saw the publication of Adam Smith's *Wealth of Nations,* the advent of Wilkinson's boring machine, and the first working model of Watt's steam engine. This period is generally considered the beginning of the Industrial Revolution. In the water supply industry, however, this revolution began almost 200 years before 1700 with the use of pumps and reservoirs.

Today the world is on the threshold of an even greater period of growth and change in technology, business, and economic affairs. The long-range trend shows no sign of reversal; it is most likely to continue at an accelerated pace. New managerial concepts and techniques are constantly being developed to meet this challenge. The progressive executive realizes that yesterday's approach is adequate only for yesterday's conditions. New principles, techniques, and procedures are needed if managerial abilities are to keep pace with the changing business environment.

Importance of Reports

The most essential tool of the new environment is communication, and it is the purpose of this article to discuss some of the techniques that are being used today to develop sound and informative reports for management.

The definition of reporting set forth in the *Accountant's Dictionary* is: "the giving, often periodically, of information to others." This authority further states that the essentials of reporting are brevity, simplicity of language, and intelligibility. Although this definition does not use the term, "communication" is probably the best word to describe a properly prepared report. Another term often used for a good system of reporting is "feedback." This word usually applies to reporting on control of operations, and, because it appears to indicate the movement of information in both directions, the term has definite appeal.

Space does not permit discussion of all of the kinds of reports being prepared for today's water supply executive. Certain reports are essential to operating and control of a water utility, however, such as the balance sheet and income statement. These should be supported by whatever control reports the executive needs for application of management-by-exception principles, and for discussion with employees at operating levels. This group of reports includes statements of job costs, monthly reports of operating cost, labor reports, and consump-

tion reports. Such reports are distributed at different levels of management to afford greater control.

Why are these reports important to the executive, and what benefits can be derived from their use? The answer to this question requires analysis of the individual organization and the executive. In respect to the executive, consideration should be given to his specific interest. It is often important to develop an indoctrination program for the recipients of reports at both the executive and foreman levels in order to impress upon them the need for useful control information and to provide guidance as to how to decide upon appropriate action to correct deficiencies shown by reports.

Just as accounting often is called the language of business, reports are the tools of executive control, and usually fall into two classes: reports of financial position and reports of operating results. Each serves a different purpose in management control and is of major importance in decisive management. The information furnished by accounting reports has a dual control purpose—the control of current and future operations.

Reports of Financial Position

Accounting is the art of recording, classifying, and summarizing financial transactions and events and interpreting the results. The purely recording function of accounting, although indispensible, concerns only technicians. Because business occurrences that affect the books of account are numerous and varied, top levels of management may easily fall into the error of permitting the complexity of bookkeeping and account processes to blur their vision of what is significant or insignificant.

The analytical and interpretive functions of accounting are of two kinds. One is intended to afford aid to management in the conduct of business and is of interest mainly to executives; the other consists of presenting statements relating to the financial position and results of operations for the guidance of directors, stockholders, bondholders, creditors, and others.

The financial statements generally considered most useful are the balance sheet and the income statement. Management must know the extent of company capital, how it is invested, and the shares of various parties in that capital. Management also must know whether the several items of capital are properly apportioned and observe whether the increases, decreases, and shifts from one form to another indicate a healthy condition or otherwise. For this information management looks primarily to the balance sheet or statement of financial condition.

The balance sheet is a statement of company assets, liabilities, and net worth at a given time; it is a summary of company properties, correctly valued, and of the equities of various parties in the aggregate of those properties. The properties are usually grouped according to nature and relative proportions, whereas liabilities and net worth are grouped according to the origin and character of the claim they represent.

Analysis of Statements

The study of financial statements proceeds along rather well established lines. Certain facts about a business are agreed to have special significance for particular purposes. These facts are of two general kinds, one developed by analysis and the other brought out by comparison. Analysis of statements nearly always involves comparison of some sort. The distinction between analysis and comparison is that

analysis refers to the breakdown of a statement into simpler or more meaningful terms and may involve comparison of different items within the statement, whereas comparison signifies the observation of similarities and differences between essentially like items in changing situations or points of time, as evidenced by two or more statements of the same general types.

Analysis of financial statements can be accomplished in several ways, but certain methods are more commonly employed than others. One method deals with relationships within a single statement. Some comparisons that should be made in the analysis of the balance sheet are the ratios of:

1. Current assets to current liabilities
2. Fixed assets to current assets
3. Fixed assets to tangible net worth
4. Fixed liabilities to current liabilities
5. Current liabilities to tangible net worth
6. Total liabilities to tangible net worth.

Another analysis deals with relationships between statements, chiefly between the historical items of the income and expense statement and financial items of the balance sheet such as:

1. Net income on tangible net worth
2. Net income on net working capital
3. Ratio of revenue to tangible net worth
4. Net revenues and income to utility plants
5. Cost and income above the line to utility plant
6. Revenues to accounts receivable.

Both of these methods of analysis add to the total knowledge about the business, and serve to make the basic facts more meaningful. Additional light can be cast upon conditions by comparison of these data with other, similar data.

Among the more frequently utilized comparisons are those of:

1. One period with previous periods for the same company
2. One part of the company with another
3. One company with others of comparable size and in similar fields.

In connection with comparison of financial data within its field, AWWA deserves credit for being a leader. The Association, assisted by the Municipal Finance Officers Association, provided one of the early uniform systems of accounts to be accepted by American business (*1*). The only other group to accomplish as much is possibly the Retail Dry Goods Association. AWWA can be proud of its contributions.

Significance of Analysis Data

Space does not permit full discussion of the meanings of specific kinds of data gained from analysis of statements. The facts in each individual operation, the year and season, and other items must be considered. A brief discussion of a few of the ratios mentioned may be of value, however. The ratio of current assets to current liabilities is uniformly termed the "current ratio," and is one of the more important indexes to the financial position of a business. A current ratio of 2:1 is applied almost invariably in considering the financial soundness of a company. The 2:1 formula may be adequate, but it is not sufficiently scientific to be considered universally applicable, because it does not take into consideration other significant relations, such as variations in types of businesses, inventory turnover, terms

of credit, territory served, and seasonal influences. Management in many companies goes further to compare the strictly short-term items (cash and trade accounts receivable) with current liabilities, to determine the ability of a business to pay its obligations even in the absence of continuing sales and conversion of the proceeds into cash. Water utilities should use sound judgment in respect to this ratio. Current assets should always be equal to or more than current trade obligations and debt service accruals.

The ratio of fixed assets to tangible net worth is significant for determination of the relative liquidity of a business at different times. If too great a part of net worth is represented by fixed assets, there is danger that too much dependence will be placed upon creditors for operating capital. Just what this ratio should be is indeterminate, but management should make sure that enough assets are kept above the current line to meet obligations.

In any business the ratio of total liabilities to tangible net worth is important, both from the standpoint of the creditors and from that of the owners. The proper ratio is indeterminate, but tangible net worth should be in excess of total liabilities—that is, the owners should have a greater interest in the business than the creditors. It may be presumed that the owners will put forth efforts in proportion to their investment and seek to decrease loan capital and increase share capital. If the tendency from year to year is in this direction, the company's condition may be regarded as improving. It is important that this ratio be computed, as it produces a figure which moves in unison with the current ratio. Long-term debts, such as bonds outstanding, with the exception of current maturities, are often considered a part of capital.

The ratio of revenues to accounts receivable, sometimes referred to as "account turnover," is an important one because it reveals how rapidly the accounts are being turned over; stated another way, it shows whether collections are in accordance with the terms of credit extended by the company.

In addition to analyzing relationships of certain items within the balance sheet and the relationships between balance sheet items and operating items, management may also be aided by a Statement of Application of Funds. In comparing the financial position of the company at the beginning and end of a given period, management may be confronted with seemingly contradictory circumstances. For example, it may be shown that the company has made a profit during the period and that it has a larger net worth at the end of the period than at the beginning, although its cash balance and working-capital position have been substantially reduced. This may be attributable to the investment of large sums in fixed assets, to the retirement of long-term indebtedness, or to other causes.

The best aid in answering questions on these points is the statement of application of funds. This statement sets forth, first, the amount of funds or working capital that has come into the company during the period and, second, the disposition that has been made of the funds. Common sources of funds are profits (before deductions for items that did not affect cash), borrowed capital, sale of fixed assets, and issuance of new capital stock. The channels into which these funds commonly flow are cash dividends paid, purchase of additional fixed assets,

other fixed investments, and retirement of long-term indebtedness. Any difference in the amount of funds provided and the amount of funds expended will be reflected in the working-capital position of the company.

In analyzing statements, management should direct its attention to the reconcilement of surplus. The statement of surplus is the connecting link between the profit and loss figures shown by the income statement and the surplus figure shown on the balance sheet. The profit and loss figures have been obtained, the surplus is known, but the statement of surplus serves to relate these two items to the previous surplus.

As additional aids to management, statements other than those discussed here can and should be prepared for special purposes. A statement setting forth the aging of accounts receivable is helpful in many ways in determining collection policies and the effectiveness of credit personnel. Slow-moving products and obsolete inventory should be set forth in a statement to aid management in taking corrective measures. These are examples of the many special-purpose reports that can be helpful.

By developing useful relationships and comparisons and by being provided with appropriate statements, management can function with the confidence that its policies are based upon a thorough understanding of past and present conditions.

During the past few years a new term has been used more and more often; the term is "population explosion." The significance of this term is being felt in increasing demands on the water systems. It is felt in even greater measure in the need for funds to finance new facilities. These needs give the financial statements discussed here greater significance, because investment bankers and bond purchasers depend upon financial statements in order to make their decisions on such risks.

Reports of Operating Results

Reports of operating results provide information as to the use of the assets and manpower of the company, and disclose the source and the cause of profits and losses. The value of these reports as tools of sound operating management is immeasurable. The statement of income might be considered the most important tool of top-level management in this class. Unfortunately, it is often so condensed as to be of little value to the executive as a tool of management. The system in use by AWWA has been designed so that this should not be true.

The detailed statement of revenues and operating expenses provides information that is effective in the control of operations when used in conjunction with comparative information such as budgets, results of the preceding year, and other operations. To use this tool in management does not require an understanding of its preparation. The ability to interpret it intelligently and accurately, however, is essential to its effective use. When profits are decreasing, alert management generally pursues two policies simultaneously: [1] the reason for decreased revenues is investigated, and, where necessary, rate increases are sought from regulating authorities; and [2] the amount and the percentage of each expense item in the income statement are compared with the amount and percentage of the corresponding items for the previous period to ascertain where expenses can be reduced. The logical

emphasis is on increased revenues and on decreased expenses.

Many other statements are prepared to assist management in control, and most of them are found to represent the contents of the balance sheet or income statement in greater detail or for shorter periods, as in daily and weekly reports. Such statements are primarily used for control at second-echelon management levels or are the results of "management by exception."

Budgets

The use of comparisons has already been mentioned. This is probably one of the more misused tools of business today. The reason for this is that comparisons often are made with a previous year without the knowledge of how effective the operation may have been for that year. It is easy to compound inefficiency if a poor year is used for comparison. This does not mean that such comparison should not be made, however.

Budgets are not usually subject to these weaknesses because they are developed from information that has been adjusted to provide a more realistic measurement of activities. A budget usually consists of a financial plan serving as a pattern for and a control over future operations, an estimate of future cost, and a systematic plan for the utilization of manpower, material, or other resources. Budgets assume varying forms, but they can generally be divided into two main classes: [1] capital budgets, which are directed toward proposed expenditures for project activities, such as utility plant expansion; and [2] operating budgets, which are directed toward planning and controlling program activities. The operating budget can be, and usually is, subdivided into functional classifications. Most budgets are a combination of the capital and operating budgets.

The modern budget may be compared to navigational charts and maps, because they are as necessary to the successful operation of modern business as charts and maps are to the captain who sets out to sea. Although no alert person would attempt an extensive trip without a map, business men, on the other hand, will often attempt to operate a company without a plan for future direction. Often the result is failure.

Budgets should be prepared from the best information available, and, although setting a goal that requires full effort on the part of operating personnel, they should first be realistic. If the level of operation varies to a material extent, the budget plan should be flexible so that a fair measurement can be made.

There are many methods of cost control that can be applied to budgetary procedures. The important points to consider in the application of a method are the effect it will have on the budget from a realistic viewpoint and whether it can be applied consistently. The budget should include all expected costs and should be the real yardstick for management control.

The use of the principle of standard cost is not only possible in the operation of a water utility, but it is also workable, if applied realistically. This statement may be surprising to some, because the activities required in order to maintain transmission and distribution facilities are somewhat unpredictable. This may be true, but new techniques are now available for controlling the cost of such nonrepetitive activities. Control is possible through the use of statistical analyses of unpredictable jobs performed over a period of time

and the classification of such jobs into frequency brackets. The technique has already been tested and proved sound. Substantial savings have consequently been made through a better utilization of labor. This type of control is important if water utilities are to maintain their efficiency with the increased requirements being placed upon them. Where such controls are maintained, regulating authorities can be provided with sound cost information, and the utility is much more likely to win rate increase cases.

Conclusion

Reports have unlimited value in the operation of a modern business, provided that they are properly prepared and analyzed and are used for decisive action. Such reports should always be accompanied by a well prepared budget.

In addition to reports and budgets, management should have the advice of an accountant on bond indentures, rate cases, and other problems. There is great value in employing certified public accountants to assist in problems of finance. This group of professional men is devoted to assisting business men with financial planning. Many accounting firms now maintain a staff of qualified consultants, including engineers and psychologists, and can often supply the well-known ounce of prevention.

Of all the things that might be said about reports, however, most important is that management understand their significance, thoroughly use all the meaningful data available, and take intelligent advantage of new methods of analysis, planning, and control.

Reference

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Supervisory Control in Distribution System Operation

Panel Discussion

A panel discussion presented on Sep. 8, 1958, at the Michigan Section Meeting, Grand Rapids, Mich.

Introduction—*Kenneth H. Abrahamson*

An introductory statement by Kenneth H. Abrahamson, Design Engr., Giffels & Rossetti, Detroit, Mich.

SUPERVISORY control is the selective control of and automatic indication of conditions in remotely located units. Telemetering, which is an essential accessory, is defined as the remote transmission of a measurable value, with the value reappearing on a meter at the central location. The combination of supervisory control and telemetering can thus be employed to operate remote equipment and to observe the effect of the operation on the overall system.

The proper devices at remote locations can provide positive control from the master location of all the components in the system. Pumps can be started and stopped and valves operated as required to meet the load conditions of the distribution system. Levels, rates of flow, and pressures can be measured and telemetered to the master location, giving the operator a complete picture of his entire system. Information on troubles, such as excessive bearing temperatures, may also be relayed to the operator.

Additional refinements that are available include automatic starting or stopping of pumps as the load varies, staggering of pumps to equalize wear, and even automatic typing of pumpage rates, pressures, and levels on the master log sheet.

It can thus be seen that the degree of control available is limited only by what is wanted or needed for the specific installation. Descriptions have been published in recent issues of the JOURNAL of systems ranging from simple applications for controlling remote pumps to very extensive facilities similar to those planned for the Philadelphia water department.

Principle of Remote Control

The fundamental principle involved in remote control consists of sending and receiving signals between the control station and the remote installation with the necessary electrical equipment to translate these signals into the appropriate action. The signals may be transmitted over wires or sent through space as radio waves; the means for this transmission is called a channel.

The principle is essentially that used in a dial telephone system. When one lifts the receiver, his channel is con-

nected to the main switchboard. Dialing the first two letters produces a signal that represents the exchange being called and the channel is routed to that exchange. Additional numbers are dialed and the resulting signal connects the channel with the desired party. Only those relays sensitive to the dialed pattern or code will close, and the proper connection is made. Whether the signal rings a telephone or starts a pump, the principle is the same.

The usual means of signal transmission is by wires; these may be a leased telephone circuit or a privately owned cable. A single pair of conductors can be used for each location being controlled, although it is possible to control 4–7 locations with a two-wire circuit connecting all points. As distances increase, or where the topography presents problems, the microwave technique provides a solution. In either case, voice communication can also be carried on the channel.

The signals must be so coded that each signal developed at the origin can be recognized at the point of reception. This is obviously required in order that a given signal can be associated with a particular pump unit, a specific order to do something, or a process measurement. To achieve this identity, signals are transmitted as short d-c pulses or as an a-c pulse or continuous a-c signal.

With the d-c pulse method, differences between signals are obtained by varying the number of pulses per group, varying the length of individual pulses, or varying the time between pulse groups.

The a-c method usually employs frequencies in the audio range. The signals may be pulses or continuous tones. Identity of signals is obtained by varying the tone frequencies or the sequence of tones in a group, and four different tones usually suffice. Either method will satisfactorily transmit information, although each has its staunch supporters among the engineers.

Operation Controls

The operational application of these signals may be best understood by describing a theoretical sequence. If an operator wants to put a certain pump on stream, he takes the following steps:

1. He actuates the control switch of the desired unit and a signal of perhaps two pulses per group is sent over the channel to the pumphouse. Only the relays on the particular pump selected are sensitive to this pattern, and they close, rendering the pump meter starter operable. At this point certain systems send a signal back to the control station lighting a white lamp and verifying selection of the proper pump.

2. The operator then depresses the start pushbutton originating a new signal which is transmitted to relays that control the pump motor starter. These relays close an electric circuit and the pump is energized.

3. As the pump comes up to speed, a pressure switch on the discharge closes and a signal is sent to the control point, thus verifying pump operation by lighting a green light.

The operation described above is called a simple discrete control with supervisory signals, and is about the simplest system conceivable. To this basic system, accessory features may be added to handle such things as abnormal level, distribution or supply pressures, water hammer, power failure, and equipment malfunction.

Telemetering

More facilities must be provided for the operator than mere operation of equipment. He needs flow rates and pressure gages to see what is happening in the system. Thus, data transmission or telemetering is necessary.

Telemetering equipment may consist of a transducer, a converter transmitter, and a receiver. The transducer may work in conjunction with, for instance, a venturi tube, where changes in flow can be related to electrical signals. The output of the transducer is fed to the converter–transmitter where the proper code signals are originated. These signals then are sent over the channel to the receiver where the reconversion takes place. The decoded signal may then register on a panel meter, operate an electric typewriter, and visually show the measurement being made. The metering may be continuous or intermittent, depending on the equipment used.

Conclusion

The value of supervisory control has been recognized by the electric utilities, who have used it for over 20 years for control of distribution facilities, substations, and even complete hydroelectric-power stations. Especially significant is the proved fact that operation by remote control is just as reliable as operation at attended stations. Savings in operating costs are readily apparent, owing to better utilization of manpower and increased operating efficiency. Centralized control actually results in personnel advancement, because trained men can be released from operator jobs for use in a supervisory capacity in the overall system operation.

Flexibility is inherent in automated systems. As the needs change in an installation, modifications can be easily made to expand the field of control or increase quantities being telemetered. Later additions of data logging and handling can be made with ease.

The subject of supervisory control is intensely interesting because of the great potentials of this tool. Its future is bright and water utilities will some day wonder how they operated without it.

——Controls at Grand Rapids, Mich.—*Spencer G. Ferris*——

A paper presented by Spencer G. Ferris, Supt., Div. of Water & Light, Grand Rapids, Mich.

Grand Rapids uses a pulse coding system for supervisory control. This system employs standard relays because of their extreme simplicity and dependability. It is said that an installation made in 1921 is still in continuous service. Contacts of the relays are mounted on leaf springs made of German silver. Each spring has double contacts made of a special alloy of gold and platinum. The armature is the only moving part of the relay and operates on a knife-edge bearing. This eliminates the use of a pivot and the application motion of the armature to the leaf spring is by direct pressure. It is claimed that there are no parts which can become loose or change in adjustment. In essence then, a coded number of impulses is sent to a receiver which decodes them and instigates the desired operation.

Grand Rapids was fortunate in having the necessary conductor line for the installation. It is interesting that all stations are connected and controlled by a single pair of conductor wires.

Among the many improvements recently completed in the $2,500,000 modernization program, two new booster stations were added, bringing the total to six. An outmoded type of control formerly operated four of the stations, but it required constant and heavy maintenance. Now that instrumentation has been satisfactorily installed, along with telemetering recorders, the operator at the main Coldbrook Pumping Station can start and stop any of the pumps located at the six booster stations, close valves, and perform any of the necessary operations by remote control. It also enables the operator at the Coldbrook Station to see at a glance the entire operation of the water system and integrate its operation.

Operation of Controls

In order to gain maximum safety for a system of this kind, it is necessary that the operator know exactly whether the valves are set correctly, whether the source of power is available, and a number of similar items. The operator first must select the function he wants to perform and then check for proper setup. This is done by the supervisory control system which returns an "all clear—go ahead" signal to the operator before the valve or pump function is performed. Once the selection has been made and clearance is received by the operator, then he performs any of the valve or pump operations. A light indicates normal operation or a fault, and when a fault occurs, an alarm sounds. This part of the supervisory control covers the widest range of functions.

Pump discharge pressures and station flow rates are telemetered back to Coldbrook Station where they are recorded on instruments. A house phone is located in each station and is also available for use as part of the system.

The Grand Rapids supervisory control system cost approximately $67,000 and was installed by one of the local electrical distribution contractors. The contract provided for a 1-year guarantee after acceptance, covering any electrical and mechanical defects and all materials and workmanship.

As mentioned before, the city provided the control lines but if these had not been available, telephone lines could have been rented. The city also provided all the pipe, venturi tubes, alarm devices, and recording equipment.

—Controls at Highland Park, Mich.—*Vernon L. Hinebrook*—

A panel presented by Vernon L. Hinebrook, Supt., Water Dept., Highland Park, Mich.

Highland Park, Mich., is a city of 42,000 population, 3 sq mi in area, almost completely built up, and entirely surrounded by the city of Detroit. There was a gradual population decrease until shortly after World War II, when water demand increases of about 3 per cent per year were recorded. By 1953 peak demands were met with great difficulty.

The basic weakness in the Highland Park system was the inability of the 11.5-mi, 30-in., raw-water line to deliver its design capacity of 16 mgd.

Repeated mechanical cleaning to remove tubercules and chlorination to control slime growth were of only temporary value. Cement lining of the pipe was also considered, but it became more and more apparent that even with full capacity restored the demand would exceed the supply.

Improvements and Automation

Early in 1954 the water department submitted an expansion program to the city council that included a booster station to be located midway in the 30-in. raw-water line. It was calculated that this facility would increase the raw-water supply about 40 per cent. It was proposed that two 11-mgd, high-rate clarifier units be used to process the additional water. Other steps to improve the system were recommended, including an additional 3-mil gal clear well, fortification of weak points in the distribution system, and automation of the Grosse Pointe Farms Pumping Station. The recommendations made were accepted and construction of the booster station was begun. It was ready to operate in June 1956.

Automatic-Control Scheme

Automatic operation of the booster station is accomplished by means of a telemeter unit located at the treatment plant. The two stations are connected by a pair of telephone wires, which transmit audible tone signals from the control point to the supervisory unit and then back to the control. A polarized d-c control is activated by a transmitted positive d-c signal calling for a start or increase, or a negative d-c signal for stop or decrease. The maximum d-c voltage is 50 v at 10 ma.

The telemeter has a scanning device, which scans each of 18 position indicators at 4-sec intervals. The indicators record suction pressure, high discharge pressure, motor overload, bypass valve open and closed, discharge valves open and closed, auxiliary water pressure, low line failure, bearing temperature, building temperature, high sump level, and vandalism. All of these conditions are reported on lighted name plates; any malfunction of the equipment will sound an alarm.

When an operator stops the scan control system on a particular function in the scanning cycle, the operational condition (pressure, percentage of valve open or close, or suction pressure) associated with that function will be immediately displayed on the 6-in. supervisory receiver (dial gage) in front of the operator. The condition will remain on the supervisory receiver until the scan control system is returned to automatic operation.

Valve Control

The opening and closing of valves must function in a preset time or the pump will automatically shut itself off to prevent damage to the equipment. If suction pressure is low, a light is flashed on the telemeter and an alarm sounds and announces the condition. Pressure usually can be corrected by throttling the discharge valve of the pump, using the valve control lever on the telemeter. If this does not correct the condition and the pumps begin to cavitate, the station will automatically shut itself off to protect any equipment that might be damaged.

If there is power failure at the booster station the fail-safe relays and solenoids are activated. The solenoids on the bypass valve and on discharge valves of pumps are deenergized, allowing water pressure to the hydraulic cylinders and starting the discharge valves on their closing cycle and the bypass valve on its opening cycle.

Fail-Safe Features

The purpose of fail-safe controls is to prevent damage to equipment should one or more of the following conditions exist:

1. Overload shutdown of an operating pump
2. Incorrect response to a startup or shutdown order
3. Station suction pressure too low
4. Malfunctioning of bypass valve
5. Refusal of discharge valve to open or start
6. Incorrect positioning of manual gate valve

With any of these fail-safe shutdowns the discharge valve of the pump will be automatically closed as the bypass valve is automatically opened. In this booster installation the fail-safe device is extremely important, as the high-pressure lake station operates independently of the booster. In the event of a malfunction at the booster station it would otherwise be quite possible accidentally to pump into a closed system.

The discharge valve of each pump and the bypass valve have a valve position transmitter. When an operator at the treatment plant places his supervisory control system in the selected valve position, the 6-in. supervisory receiver (dial gage) immediately reads position information for the valve. He can also watch the valve being closed or opened by the percentage of dial gage.

Seasonal Alarms

Inasmuch as the booster station is used only in summer, only information concerning the unattended building is desired the rest of the year. This is accomplished by means of a seasonal, alarm transfer control. The supervisory controller unit permits transfer of only four alarm functions: [1] building temperature too high; [2] building temperature too low; [3] sump level too high; and [4] vandalism. These conditions are reported by a direct connection with the audible alarm unit at the water treatment plant during seasons when the booster station is inoperative and the supervisory control system is shut down. This can be done by stopping scan on the seasonal-alarm position transfer and then shutting the telemeter off.

In July 1958 two reactivator units with a capacity of 22 mgd were placed into service. These units came equipped with automatic blowoff equipment. The rest of the operations, such as alum, carbon, and coagulant-aid feeds, are remotely controlled from the filter plant. Motor-operated valves are remotely controlled from the pump station. Valve positioner gages indicate the extent to which a valve is open.

In spite of the relatively trouble-free units supplied today, intelligent, routine inspection is certainly required. Experience has shown that the successful operation of automatic equipment requires the services of either a factory-trained service man or a man already in the utility organization who has had an electrical or electronic background and can be trained to maintain the equipment. Service from the manufacturer tends to be expensive and is rarely available in emergencies.

The success of automation of the booster station at Highland Park has made automation of the low-lift Grosse Pointe Farms Station a high-priority project for the future.

Preventive Maintenance of Pumping Units

Otto M. Kristy

A paper presented on Sep. 24, 1958, at the North Central Section Meeting, Duluth, Minn., by Otto M. Kristy, Supervisory Engr., Field Service, Centrifugal Pump Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

PREVENTIVE maintenance of pumping installations should begin with the selection of the proper pump to do the job. If this maintenance is continued during the installation, startup, operation, and shutdown of the pump the useful life of this equipment can be appreciably extended.

Selection

This article will not cover in detail all of the factors involved in proper pump selection. Some explanation of the more important considerations in pump selection, however, will allow the required pump maintenance to be reduced.

1. All the materials selected should be capable of satisfactorily handling the fluid being pumped.

2. The bearings and lubrication should be adequate with respect to ambient temperature, dust, and moisture conditions.

3. In order to handle the fluid the correct decision as to whether to use a mechanical seal or packing in the stuffing box must be made. In efficiently handling the fluid to be pumped the shaft sleeve and packing are also of particular importance; the materials of which they are made must be carefully chosen.

The first consideration is the materials of which the pump is made. Naturally, this is an important factor in the initial cost of the equipment. A high initial cost for better materials to withstand corrosion, abrasions, temperature, dust, and dirt may be much cheaper in the long run than continuous overhaul and repair of a pump made of less expensive but inferior materials. When costs of labor, materials, and production time lost are added up it frequently is found that better materials actually begin to save dollars after a very few years of operation.

The second consideration, the correct choice of kind or type of bearings and lubricant with respect to ambient temperature and moisture and dirt conditions, is also important. For example, if a pump is to handle boiler feedwater at 325°F a great amount of heat will be conducted down the shaft to the bearings. It is necessary, therefore, to install oil-lubricated bearings and a lubricating-oil system that includes a cooler. If any other type of lubrication system is used excessive maintenance costs can be expected.

Probably the one pump component that causes more maintenance difficulty than any other is the stuffing box. The correct choice as to kind and material at the time of purchase will eliminate many operating troubles. Consideration should be given to the use of me-

chanical seals if no leakage from the pump is desired, if the fluid being pumped is not abrasive, and if the temperature and pressure are not excessive.

If a packing stuffing box is used a shaft-sleeve material should be chosen that will give maximum service and will not be attacked chemically. The packing should be chosen with the sleeve material in mind and should be capable of withstanding the chemical attack of the fluid as well as the effects of temperature and pressure.

Installation

Preventive maintenance will be most effective if it is begun at the time of the purchase of the equipment rather than after it has been installed. Even after installation, however, there is much that can be done to minimize the amount of maintenance required to keep the equipment operating efficiently.

When installing a pumping unit there are several points to consider carefully. The pump and drive should be located so that they are easily accessible during operation. This will allow the operator to inspect the equipment during operation and easily to perform minor maintenance tasks, such as packing adjustment and bearing lubrication.

In selecting the site of the pump an attempt should always be made to keep the suction and discharge piping as short, straight, and simple as possible. If a compromise must be made the discharge piping should be lengthened instead of the suction piping. A smaller number of fittings for the suction piping will decrease losses when conveying the fluid to the pump and minimize the opportunities for air pockets or bubbles to collect and cause air-binding of the pump. If a long suction pipe cannot be avoided the diameter of the pipe should be increased to a minimum of 1½–2 times the area of the pump suction nozzle. The piping should be laid so as to rise steadily to the pump. A concentric reducer should be installed at the pump suction flange to prevent air pockets and loss of prime.

The suction pipe should be sufficiently submerged to prevent sucking in of air at low water. Normal submergence depth will average about three times the diameter of the pipe, which should be sufficient to prevent drawing a vortex during operation. Prior to startup the suction pipe should be tested for air leaks over its entire length.

Experience has shown that it is always wise to provide overhead lifting devices which can easily handle the heaviest piece of machinery present and thereby facilitate removal and repair operations.

The room surrounding the pump and drive should be well lighted, dry, and properly ventilated. This will prevent exterior corrosion and deterioration of the machinery and will facilitate the work of the operating personnel in periodically checking the equipment in operation.

The foundation should provide a rigid, firm, and permanent support for the bedplate or the sole plates, or both. It should be capable of absorbing any vibration imposed by the rotating pump and drive. Most pump foundations consist of concrete laid on solid ground, bedrock, or pilings. Foundation bolts should be either set in the concrete and accurately located on drawings or set in a template and surrounded by a pipe sleeve with a diameter about three times larger than that of the bolt. The bolt must be firmly anchored if it is placed in the

concrete, but in the pipe sleeve it should be free to allow minor shifting of the bolts to suit the bedplate drilling.

If a foundation is formed on a floor, a platform, or any similar structure it should be set over support beams, walls, or footings. The system must be rigid enough to prevent distortion of the bedplate and misalignment of the unit. This type of foundation is usually not recommended because it can be expected that support beams, walls, and footings will sag or settle with time and misalignment will occur.

Before the pump unit is grouted a form should be placed around the entire bedplate to allow at least ½ in. of grout to come out under the bedplate drip lip and fill the entire space between the bedplate and the foundation. All air pockets or voids should be eliminated from the grout.

An accepted mixture of grout consists of one part cement and two parts sand, mixed with sufficient water to allow the mixture to flow readily under the bedplate and around the form. Sufficient head and agitation should be provided to be certain complete filling has been accomplished. The grout should set for 2 or 3 days, depending on relative dampness, after which all foundation bolts should be securely tightened. The shim pack (preferably rectangular or horseshoe-shaped steel plates to enclose the foundation bolt) should be left in the ground permanently.

Prior to grouting, the mounting pads or sole plates must be leveled by shimming adjacent to each foundation bolt. The shafts of the driving mechanism and the unit it drives must be level and the couplings aligned.

After the grout has set the suction and the discharge piping should be attached to the pump casing. No strain should be exerted on the casing because this will cause it to distort, the rotating element will rub and possibly seize, and there will be a coupling misalignment.

After all the piping has been attached the alignment should be checked and then rechecked after the unit has been placed into operation and brought up to full load for the first time. If the foundation has shifted it should be permanently corrected at this time. If the piping has shifted it must be properly supported to prevent any strain on the pump throughout the load-and-temperature cycle over the pumping range.

Probably the only single factor that requires a great deal of maintenance and repair but can be easily and accurately inspected and corrected is the coupling alignment of the pump. Coupling misalignment can damage couplings, bearings, shaft sleeves, packing or mechanical seals, wearing rings, and the shafts. The vibration and noise level of the machinery will also be affected.

The discharge piping, although not as critical as the suction piping, is important in keeping the pumping unit free of excessive maintenance costs. The discharge piping should contain a check valve and a gate valve near the pump discharge flange. The check valve will protect the pump from backflow and water hammer when it is shut down. Discharge piping should also be supported to prevent strain on the pump casing.

In any installation attention must be given to the driving machinery because improper handling of this machinery can also have damaging effects on the pump. Proper installation and a check of the rotation before operation are necessary for trouble-free service.

Water may be required to cool bearings or flush the stuffing box. If so, careful attention must be given to the water and the water connections. Required pressure and quantity of flow must be checked, and also the chemical constituents and foreign-particle content of the water. Foreign particles can plug pipe fittings and their introduction into the stuffing box can cause severe material damage and complete failure of the pump. Chemically active service water can be detrimental to any material not capable of withstanding it.

On many auxiliary or service lines it is wise to include strainers, pressure gages, flowmeters, or alarms to indicate during operation whether or not the pump is operating normally. The loss of service water may result in complete failure of the pump.

Because of the increase of automation in pump operation it is wise to consider installation of suction and discharge pressure gages and an ammeter, a voltmeter, and possibly a flowmeter. Installation of such devices increases the maintenance required but the complexity and remoteness of operation in many plants requires alarms, signals, and controls to assure good operation of the pump and its drive.

Many pumps will require vent lines, pressure-relief lines, and recirculation lines. The proper installation of these connections and of the various controls and indicators required to operate them is mandatory for maintenance-free service.

Startup

After installation has been considered from the point of view of preventive maintenance startup is the next step. Certain preliminary factors must be considered before the pump can be started.

Suction-line flushing prior to initial startup has a direct bearing on maintenance required and if neglected can be the cause of much preventable maintenance expense and pump damage. Complete and meticulous flushing of the entire suction system is necessary to remove all sand, silt, scale, rust, and weld beads left in the suction tank or pit of the piping which connects to the pump. Small particles—about 0.010 in. in diameter or less—can get into the rotating clearances and cause cutting, galling, and complete seizure.

The suction tank or pit can be scrubbed and hosed down; the connecting piping, vent lines, gage lines, and control lines can only be flushed. However, velocity of the water is the active agent in cleaning the pipelines and velocity can only be increased, in this case, by increasing the quantity. A sufficient quantity of clean water must, therefore, be flushed through these lines, sometimes as much as 30,000–40,000 gpm. It is also advisable either to tap the pipelines with a hammer or to raise and quickly lower the fluid temperature about 100–125°F. This will cause rust and weld scale to be broken loose either by the vibration caused by the hammer or by the expansion or contraction of the pipe or tank due to temperature.

Suction screens should not be depended upon to catch the foreign material before it enters the pump. If the screen is fine enough to catch material 0.010 in. or less in diameter the screen will plug rapidly and the pump will lose water, run dry, and seize. If, on the other hand, the screen has a mesh of $\frac{1}{8}$ in. or larger and does not plug rapidly it also will not catch the fine

material that can get into the close running clearances. The large-mesh screen will catch only tools, rags, and similar objects, which in all probability would not seriously affect the pump mechanically. The only safe and sure way to prevent foreign material from entering the pump is to get it out of the system at startup and keep it out.

Other steps which should be taken before the pump is started are:

1. A complete inspection of all the components of the pump should be made to be certain the unit is ready for operation.

2. The bearings should be lubricated with the proper grade of lubricant specified for the job and in accordance with the quantities required for each bearing.

3. The pump should be primed or filled with the liquid to be pumped.

4. All auxiliary water, vent, pressure-relief, recirculation, and other lines should be placed in operating condition.

5. The suction line to the pump should be completely opened and all gages and alarms be placed in operating order.

After these steps have been taken the driver can be started and the pump brought up to operating speed. A quick check of all bearings, stuffing boxes, gages, instruments, and controls can be made while the discharge valve is closed. The time element for this checking period should not, however, exceed about 2 min. With the discharge valve closed and no water being delivered the pump will overheat and seize due to the shutoff horsepower of the driving motor heating the water in the closed casing as the pump impeller churns the fluid in the casing. If in the course of normal operation it is necessary for the discharge valve to be closed, or almost closed, a bypass line which can handle from 5 to 10 per cent of the rated flow should be installed.

Naturally, the more complex the pumping installation the more extensive and comprehensive will be the startup technique required. However, regardless of the size of the installation if the pump is properly primed, air is purged from the system, and other points are checked then the suction and discharge gages will record good hydraulic operation. If the suction gage shows a considerable drop compared to the nonoperating reading or if the discharge pressure does not immediately register the unit should be stopped at once and not put into service until the source of trouble is eliminated.

Operation

In order to continue preventive maintenance during operation certain factors must be checked periodically while the pump is operating.

1. The bearings should be carefully checked for signs of overheating. It is wise to inspect, drain, flush, and relubricate bearings during the first few months of operation in order to establish an individual timetable for bearing lubrication. The ambient temperature, the dust and dirt condition, and the humidity will make the timetable for one installation differ greatly from that of another. There may even be considerable differences in timetables between one pump and another in the same plant.

If questions arise as to the exact kind of grease or lubricating oil to use it is advisable to have a local lubrication-supply engineer make a study to determine the proper lubri-

cant. It may be possible to use the same lubricant for several applications, thus requiring the storage of fewer types of lubricant.

Although each plant should set its own lubrication timetable, as described, oil-lubricated bearings will usually require at least daily attention and grease-lubricated bearings will require attention at infrequent time intervals, usually every 2–3 months. Care should be taken with oil-lubricated bearings to prevent the various fittings from leaking and allowing the oil to drop below the safety level or fill above the full-line, causing too high an oil level, which will make the bearing overheat. Grease-lubricated bearings must not be too full or under pressure; excessive fullness or pressure will pack the grease in and around the balls and will prevent them from rolling. This will result in the balls sliding, which in turn will cause scoring, galling of the bearing races, and rapid failure of the bearing.

2. The alignment of the coupling during operation should be checked as carefully as the bearings. This requires periodic checks to determine that the alignment is being maintained. Extensive and costly repair of the pump and drive can be expected if this is not done.

3. The stuffing box should be checked daily to determine that the proper amount of leakage is taking place. If a mechanical seal is being used many units will require either flushing or cooling and lubrication flows to the sealing faces. This pressure and capacity must be regulated and maintained during operation. When a stuffing box is repacked it should be checked to make certain that the box is clean down to the base metal and that the shaft sleeve is not cut or worn. The packing should be cut to an exact length so that the ends just butt firmly. Each ring should be pushed firmly to the bottom of the box with a packing tamping tool. The joints of each ring should be staggered 90 deg. Special attention should be paid to the water-seal ring, if one is used, to make sure it is in position directly under the flushing-line connection to the stuffing box. This requires the correct number of rings placed both in front of and behind the seal ring. When the packing is all installed and there is no pressure in the pump the gland should be securely tightened to squeeze the packing out against the stuffing-box wall and around the sleeve. Then the gland should be loosened to permit the packing to expand. Gland-bolt nuts should be retightened only finger tight. The packing should then be ready for service.

If further adjustment is required it is preferable to stop the pump, drain the casing, and repeat the entire process. Often, however, this cannot be done. If adjustment must be made on a running pump the gland should be tightened only one flat of the gland-bolt nut no oftener than once every 20 min. This will enable the packing to expand slowly so that it will not score the sleeve or burn the packing.

Shutdown

The shutdown procedure for the pump is also important in preventive maintenance. It is recommended that a gate valve be located in the discharge line. Prior to stopping the pump this valve should be closed tightly to keep the casing filled with fluid and to prevent metal-to-metal contact of the wearing surfaces. A centrifugal pump should never be throttled on the suc-

tion side, nor should it be stopped by closing the valve on the suction side. These actions will prevent the fluid being pumped from entering the casing and lubricating the close-rotating clearances.

If the pump is to be shut down for a long period of time the fluid should be drained from the casing to prevent corrosion products from filling the close-running clearances. Additional protective steps should be taken to prevent corrosion of bearings, stuffing-box parts, and couplings. The author suggests that a shut-down pump be turned over slowly by hand at least once a week.

Miscellaneous Factors

In addition to selection, installation, startup, operation, and shutdown other factors in a pumping installation must be examined for efficient preventive maintenance. Correct maintenance, as applied to these factors, should be based upon a knowledge of: pumping, work required, maximum allowable out-of-service time, and design of the pump.

Bearings

On pumping machines with horizontal shafts the thrust bearing is almost always on the outboard end. It may be either an antifriction bearing of single- or double-row design, lubricated with oil or grease, or an oil-film type of thrust bearing.

The inboard bearing may be either an antifriction-design, single- or double-row, oil- or grease-lubricated bearing, or a babbitt-shell, oil-lubricated bearing. Regardless of the type the important things to know are what kind of bearing it is and the proper lubricant to use with it. A periodic inspection schedule to check for temperature and noise, a periodic maintenance inspection, and a lubrication replacement schedule can then be established.

If the outboard thrust bearing is an antifriction bearing it is shrunk onto the shaft and held tightly with a locknut. The outer race, or races, is confined in the bearing housing to prevent end movement and to absorb the thrust.

If the inboard radial load bearing is an antifriction bearing it also is usually shrunk onto the shaft and held by a locknut. The outer race, however, is either free to float in the bearing housing or the entire housing is free to float in the bearing body and cap. This is necessary in order to prevent pinching of the bearings due to shaft expansion during operation. In all cases the outer bearing race must have a close sliding fit in the bearing housing.

An antifriction bearing is a precision part and must be carefully handled with respect to cleanliness and lubrication. In many cases it is much cheaper and quicker to remove the bearing in such a way as to protect the shaft and housing and replace it than to spend time and money either to purchase or to make a bearing puller that will satisfactorily remove the used bearing. If the bearing must be pulled off it should always be pulled on the inner race and never pulled or pushed on the outer race. It may also be necessary to apply heat or dry ice, or both, in order to remove a bearing satisfactorily.

Internal Clearances

The internal clearances of a pump should always be known in order to formulate a maintenance program. Horizontal pumps of almost any size should have an axial float of no less than $\frac{3}{16}$ in. and no more than about

½ in. Vertical pumps should have somewhat greater clearances, depending upon the size of the unit.

The casing surrounding the rotor must not pinch any of the stationary parts of the rotor or they will bind and rub on the rotating element. There is usually approximately 0.003 in. clearance on the diameter between the casing and the stationary parts. The pump running clearance is 0.0010–0.0015 in. per inch of diameter of the wearing ring or surface. This clearance will vary only due to the condition of part materials, the operating temperatures, or an extremely large-diameter wearing ring.

Gaskets

When oiled-paper or service-sheet gaskets are used between the upper and lower half-casings and the bearing body and cap the gasket thickness should be $\frac{1}{64}$ in. The casing and bearing bodies are bored in place with this thickness of gasket. In order to provide proper positioning of the upper half-casing the main joint and all casing bores should always be cleaned down to the bare metal and a new $\frac{1}{64}$-in. gasket should be used as a replacement.

Wearing Rings

Wearing rings should be replaced when the clearance has increased to a point at which either the driving motor is overloaded or the pump is no longer capable of producing rated capacity. In general when the clearance has increased from two to three times its original size the rings should be replaced.

Replacement Parts

In most cases it is preferable to use factory replacement parts for a pump because this will make it possible to keep the pump equipped with parts of correct dimension, size, and material. The factory supplying replacements may also be able to recommend a change of materials or design which will make possible longer and better pump service. Standardizing pump parts will also enable the factory to ship parts in the shortest possible time and thereby minimize out-of-service time during an emergency repair.

If the pump operation is of great importance it is advisable to carry certain spare parts in stock. If the out-of-service time factor is critical a complete rotating element, including bearings and half-couplings, should be in stock; if the time factor is not critical it is only necessary to have wearing rings, shaft sleeves, packing gaskets, and bearings in stock.

Whenever replacement parts, particularly a complete rotating element, are being installed the casing and all machined fits should be cleaned down to the bare metal. The shaft should be centered in the stuffing box at each end and a check made of running clearances and axial clearances. The impeller should be set in the center of the volute to obtain stable operation and minimum thrust. If the pump has multiple impellers there must be an average setting of all impellers.

The replacement procedure is the same for vertical pumps of a volute or diffuser design. With a horizontal, volute casing design the impeller or impellers can be repositioned on the shaft by alternately loosening and tightening the shaft nuts. The shaft nut on one side is loosened and the nut on the opposite side is tightened to push the impeller toward the side with the loosened nut. Both nuts are then securely tightened.

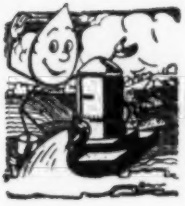
Before placing any rotor in its casing the shaft should be placed in a lathe and its entire surface indicated. The shaft and rotating wearing surfaces should be within 0.003 in. of total indicator reading.

Annual Inspection

If it is possible without jeopardizing operations the pump and drive should be subjected to a thorough annual inspection. The inspection should cover the following points:

1. The bearings should be removed, cleaned, inspected, and replaced if necessary.
2. The entire casing and the bearing body should be cleaned.
3. The old packing should be removed and the shaft sleeve should be inspected; both should be replaced if worn.
4. All of the rotor parts should be inspected and replaced if necessary.
5. If a new rotor is required it should be checked for straightness and assembled in the pump using new gaskets where necessary.
6. The casing should be checked for pipe strain and realigned and doweled if necessary.
7. The drain, vent, recirculation, and lubrication lines should be disconnected and cleaned and flushed.
8. All gages and instruments should be tested and recalibrated.

If service requirements will not allow taking the equipment down for an annual inspection then the preventive maintenance program increases in importance. This program is designed to periodically check the various items that prevent a major breakdown of the pump.



Cathodic Protection of Water Storage Tanks at Kalamazoo, Mich.

Albert Sabo

A paper presented on Sep. 10, 1958, at the Michigan Section Meeting, Grand Rapids, Mich., by Albert Sabo, Mgr., Water Utility, Kalamazoo, Mich.

FROM a study of some of the material that has been written during the past few years on the subject of cathodic protection and from the experience of the Kalamazoo, Mich., water utility during the past 17 or 18 years some definite statements can be made on the subject:

1. The original installation of cathodic protection should be made by a trained expert.
2. Cathodic protection should not be considered a cure-all; it cannot renew surfaces already pitted.
3. Cathodic protection equipment will stop corrosion if correctly designed and installed.
4. The installation cost of cathodic protection is generally about half the cost of attempting protection by coatings.
5. Taking equipment out of service to install or service cathodic protection is generally unnecessary.

These statements are common knowledge to most persons concerned with corrosion prevention. They sum up the most important features of cathodic protection.

Cathodic Protection and Corrosion

Cathodic protection, properly understood and applied, has special advantages over other corrosion control methods when used in a water utility:

1. In many cases cathodic-protection installations can be made and placed in operation without taking equipment out of service. This is particularly important for water storage tanks.
2. The surfaces to be protected cathodically do not require special preparation. Old paint films, most scales, and previous corrosion will actually reduce current-density requirements for complete protection.

In the simplest sense cathodic protection is the physical act of reversing the electrochemical force of galvanic corrosion; the result is the stoppage of the destructive process which destroys the ferrous metals.

Sir Humphrey Davy, British chemist, observed in 1824 that: "If [a metal] could be rendered slightly negative the corroding action of sea water upon it would be null." For about 100 years not much use was made of this idea, no doubt due to the lack of a simple source of current. The use of the principle for protection of steel water tanks started about 1935.

Corrosion is an electrochemical phenomenon caused by a difference in potential between various portions of the surface of a metal surrounded by an

electrolyte. In a tank filled with water the water acts as the electrolyte; in a pipe buried in the ground the ground acts as the electrolyte. When there is a difference in potential between the two there will be a flow of current, causing the metal to corrode at either the electronegative or the anodic area.

According to the theory of cathodic protection corrosion will be prevented if a direct current is imposed in such a way as to overcome the corrosion current. The metal will then become more electronegative and corrosion will cease.

A byproduct of cathodic protection is the deposit of the metals that are in the water, such as calcium and magnesium, on the walls and bottom of both tank and riser. These form a film about $\frac{1}{4}$ in. thick which resembles a very heavy coat of paint and which varies in color in different waters. It is usually either gray or white. If the current fails, if the water recedes for considerable periods, or if icy conditions make it necessary to remove the anodes this film in itself affords protection for several months.

Installation Factors

There are two factors in cathodic protection which make the installation a job for experts: the difficulty of achieving the correct current density and the design of the anode.

An examination of literature on cathodic protection indicates that current-density requirements range from 0.3 to 60 ma/sq ft or more (higher value is for the protection of iron against various water solutions). Current density must be sufficient to maintain the "electrical fence" on *all* submerged areas of the structure. Adequate current must be applied to polarize any and all surfaces of the metal to the minimum protective potential measured against a reference electrode positioned at the metal surface. The protective current density required in any particular case is governed by many factors, most important of which are: type and condition of the applied surface coatings, dissolved oxygen concentration, chemical components, conductance, temperature, pH of the electrolyte, and rate of water flow at the surface.

When the current density that will be required is established it is necessary to select the most suitable type of anode to distribute the current to all parts of the structure in contact with the electrolyte. These anodes may be electrolytic or galvanic, or a combination of the two may be used. They must be correctly positioned, sufficient in number, and of adequate length and area in relation to the metal surface to be protected. For example, a separate, full-length anode should be provided for the large risers of elevated tanks.

Electrolytic anodes may be either expendable or nonsacrificial. Both types are energized by an external source of direct current. Expendable anode materials include: iron, carbon steel, chrome steel, and aluminum. Nonsacrificial anode materials include: carbon, graphite, and platinum. High-silicon, cast-iron anodes are now available that seem to be classified between the expendable and the nonsacrificial types. They are said to have a long life and in many cases are essentially nonsacrificial.

The source of current for electrolytic anodes is usually a dry-type rectifier. There are three well-developed types of these rectifiers, usually re-

ferred to as: copper oxide, selenium, and copper sulfate. These rectifiers convert a-c current to d-c current with the proper characteristics for cathodic protection. Motor generators are also frequently used for this purpose; they are, however, most practical when the output requirements exceed 3,000 w.

Galvanic anodes are composed of any one of the metals higher in the electromotive series than the metal to be protected. For this reason these anodes are self-energized when electrically connected to the structure to be protected. Some of the materials used for these anodes are: aluminum, zinc, and magnesium. An example of the use of galvanic anodes is the widespread practice of protecting glass-lined, domestic, hot-water tanks with magnesium anodes because of possible uncoated spots on their surface.

The relatively low driving voltages of metals used for galvanic anodes, their polarization characteristics, and certain other limiting factors have until now restricted their use for cathodic protection of large, steel, water storage tanks; however, laboratory and field research conducted over the past few years seems to have developed a more efficient magnesium alloy for galvanic anodes. This alloy, together with asphaltic or other coatings, may make possible a more extensive application of magnesium for galvanic anodes.

A cathodic-protection installation in a steel water storage tank is about the same in cost as one good cleaning and painting job of the interior of the tank. Operating costs will vary with the characteristics of the water, power costs, and the condition of the structure. Generally, it might be said that an average cost of 5 cents per kilowatt-hour for current for a 50,000–100,000-gal capacity tank will amount to a total cost of about $1 per month over a 12-month period. This cost will increase proportionately for every additional 100,000 gal of capacity.

TABLE 1

Data and Costs for Kalamazoo Water Storage Tanks

Item	Edgemoor Tank	Dartmouth Tank	Mt. Olivet Tank
Capacity—*gal*	750,000	350,000	500,000
Current output—*amp*	16*	6†	3.5‡
Current density per sq ft protected—*ma*	1.2	0.9	0.46
Annual costs:			
Labor	$ 60.00	$ 60.00	$ 60.00
Rods	88.40	68.00	72.00
Current	85.00	25.90	24.00
Total	$233.40	$153.90	$156.00
Annual cost per 100,000 gal capacity	$ 31.12	$ 43.97	$ 31.20

* At 30 v.
† At 27 v.
‡ At 20 v.

Kalamazoo Tanks

The Kalamazoo water utility has three cathodically protected elevated steel tanks. On a 750,000- and a

350,000-gal tank, erected for the utility in 1940, the interiors were never cleaned of mill scale or painted, cathodic protection was installed at the time the tanks were erected. Stainless-steel anodes were used; the power source was a copper-oxide rectifier. At that time a current output of approximately 10 amp at 25 v was applied. Inspection of the tank indicated that this was insufficient protection.

Approximately 2 years later, the utility installed a larger copper-oxide rectifier with anodes more closely spaced. Because of wartime shortages iron anodes were used instead of stainless steel. This larger rectifier increased the current output to approximately 16 amp at 30 v. Approximately 4 years after the iron anodes were installed the utility replaced them with aluminum anodes, 98 ft long. The one in the center leg was $\frac{3}{4}$ in. in diameter and all the others were $\frac{5}{8}$ in. in diameter. Current was still 16 amp at 30 v. The cathodic protection obtained from these rods has always been excellent.

The water used by the Kalamazoo utility is rather high in iron content. This has made it necessary to inspect and clean the tanks annually.

The third tank to be cathodically protected was erected in 1957. The capacity of this tank is 500,000 gal. Its interior was neither cleaned of mill scale nor painted; nevertheless, inspection shows cathodic protection has been highly effective.

The $\frac{5}{8}$- and $\frac{3}{4}$-in. aluminum rods used as anodes are usually installed in May and removed in December of each year. These anodes are the expendable type with a 2-year life and they are removed and replaced by the utility's own workmen. However, this service—seasonal replacement of anodes and a check of the condition of the tanks—is available through many reputable firms at a reasonable charge.

Cost of Servicing and Current

An example of the annual cost of servicing and current for the three water tanks of the Kalamazoo utility during a typical year is given in Table 1. Labor cost, for installing and removing rods, does not vary appreciably for these three tanks, in spite of differences in their capacities. The cost is calculated on the basis of 24 man-hr (3 men working 8 hr) at $2.50 per hour and comes to $60. The aluminum rods used as anodes all have a 2-year life.

If these tanks were painted inside with two coats of red lead in accordance with AWWA standards (*1*) the rectifier output could be reduced to half that necessary for the uncoated tanks. Also, fewer anodes of smaller area would be necessary.

In 1959 the Kalamazoo utility intends to try high-silicon, cast-iron anodes which are connected with No. 8, 7-strand, polyethylene-coated, polyvinyl-chloride jacketed lead wire. It is estimated that these anodes will cost about five times as much as the anodes now being used but it is expected that these new anodes will have a 15-year life. There will also be a saving in the labor required to remove and install these anodes because they can be coiled up and stored in the tank itself.

Conclusion

The application of cathodic protection frequently presents a complex engineering design problem that is not always correctly estimated. For success and economy a comprehensive survey of the corrosion environment is the best procedure, except, perhaps, in

the simplest cases where success seems almost automatic.

Cathodic protection cannot be expected to replace metal already lost by pitting action or to cause rust formed before application of protection to vanish. Any steel surface that is submerged in water can be protected, however, if the cathodic protection installation is properly designed and installed.

Reference

1. AWWA Standard for Painting and Repainting Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks for Water Storage—AWWA D102-55T. Am. Wtr. Wks. Assn., New York (1955).

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Chlorine Derivatives of Phenol Causing Taste and Odor

Rice H. Burttschell, Aaron A. Rosen, Francis M. Middleton, and Morris B. Ettinger

A contribution to the Journal by Rice H. Burttschell, Chemist, Aaron A. Rosen, Chemist, Francis M. Middleton, In Charge, Organic Contaminants Unit, Chemistry & Physics, and Morris B. Ettinger, Chief Chemist, Water Supply & Water Pollution Program, all of the Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

OF all the organic pollutants which can affect the taste and odor of drinking water, phenol has been the most extensively studied and is best understood. Modern investigators know which wastes are its major sources, a great deal about what happens to it in a stream, and that its maximum taste-producing potential develops only after chlorination. Corrective measures are available: treatment of phenol-containing wastes and suitable treatment in the water plant to eliminate the offensive products. The methods for determining phenols are among the most sensitive organic analyses available.

Nevertheless, few points are sufficiently clarified to permit the problem of pollution by phenolics to be set aside. Discussions among water scientists, in fact, frequently center upon this problem. One reason is that the term "phenol" encompasses a family of similar compounds and information acquired about its simplest member is often applied to all phenols. Another reason is the lack of a clear understanding of the specific taste- and odor-producing compounds resulting from chlorination. Knowledge of the identity of these compounds would make more effective the available information about the behavior of phenolic pollutants, from their waste source to their final elimination.

Chlorination Products

The chlorination products of phenol in water supplies have been the subject of much conjecture. Due to the evident similarity of tastes Adams suggested (*1*) that the taste of chlorinated phenol is caused mainly by 2-chlorophenol (2-CP). Ettinger and Ruchhoft presented conflicting data (*2*):

1. The molecular ratio of chlorine to phenol required to develop maximum taste is about twice that required to form 2-CP.

2. The taste intensity of chlorinated phenol is greater than that of an equivalent concentration of 2-CP.

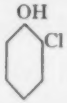
3. Further chlorination of 2-CP produces an intensification of the taste.

The widely accepted principles of orientation in aromatic substitution indicate that progressive chlorination of phenol proceeds through the stages of 2- and 4-CP; 2,4-dichlorophenol (2,4-DCP); 2,4,6-trichlorophenol (2,

4,6-TCP); and more highly chlorinated products (*3*). The structures of these compounds are:

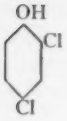
Phenol

2-CP

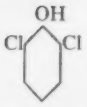


4-CP

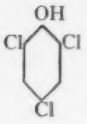
2,4-DCP



2,6-DCP



2,4,6-TCP



4,4-Dichloroquinone

From their results Ettinger and Ruchhoft (*2*) concluded that none of these compounds could account adequately for the taste of chlorinated phenol. Ingols and Ridenour also rejected these compounds as the key causes of taste in chlorinated phenol and suggested instead that a dichloroquinone is the characteristic product (*4*).

The advances in physical-research tools that have become available since the researches described (*1–4*) have provided an opportunity to reexamine the chlorophenolic taste problem. The methods that proved especially informative are: paper chromatography, infrared and ultraviolet spectrophotometry, and sensory-panel evaluation of taste and odor. The results of this reexamination showed that under water-treatment–plant conditions the reaction does proceed as had been suggested: by progressive chlorination of ortho and para positions. All of the chlorination products, it has been determined, may contribute to the intensity of taste and odor. At maximum taste and odor intensity the major contributor is a hitherto overlooked compound: 2,6-DCP. The series of reactions leading to the formation and ultimate destruction of the chlorination products involves complex kinetic interrelationships. These kinetic factors probably provide the explanation for some apparent chlorination anomalies, such as reported instances in which phenol pollution either did not result in taste formation or in which the occurrence of taste was markedly delayed.

Identification and Analysis

The paper chromatography procedure made it possible to identify some of the chlorination products of phenol in very dilute solution. The weight ratio of chlorine to phenol varied from 0.5:1 to 4:1. This range included the 2:1 ratio at which maximum taste development is said to take place (*2*). In this procedure the phenolic substance is converted to an azo dye which

is concentrated by solvent extraction and chromatographed. The characteristic dyes corresponding to phenolic compounds at each chlorine dosage are shown in Table 1. This method cannot be applied to *para*-chlorinated phenols; therefore, 4-CP; 2,4-DCP; and 2,4,6-TCP were not detected.

The taste intensity of each chlorination mixture was determined by threshold tests. The results confirmed that maximum taste is developed at a 2:1 chlorine-to-phenol ratio. The apparent proportion of 2,6-DCP was greatest at the 2:1 chlorine-to-phenol ratio. This compound had not been considered as a chlorination product in previous chlorophenolic taste studies. When the chlorine ratio was increased to the 4:1 level, which destroys the formed taste, no 2,6-DCP was detected.

TABLE 1

Paper Chromatography of Phenol Chlorination Products

Weight Ratio *chlorine:phenol*	Components Detected
0.5:1	phenol; 2-CP*
1:1	phenol; 2-CP; 2,6-DCP
2:1†	phenol; 2-CP; 2,6-DCP
4:1	none

* Traces of 2,6-DCP were suggested but were too weak for positive identification.
† Maximum taste development is said to take place at this weight ratio.

The paper chromatographic procedure could not be used for quantitative analysis for two reasons:

1. Some chlorination products do not yield extractable dyes.

2. Dyes that are suitable vary too widely in rates of formation and stability for quantitative recovery of all of them.

The ultraviolet spectrum also could not be used for quantitative analyses because the various chlorination isomers are very similar in their spectra.

Infrared spectrophotometry was used for quantitative analysis of the chlorination products at the maximum taste level. Infrared spectrophotometry requires larger samples than chromatography; therefore, 1 liter of 20-ppm phenol solution containing 2 g/l sodium bicarbonate was treated with 40 mg of chlorine. Taste threshold tests proved that the chlorination process at this concentration was the same as at the customary 1-ppm concentration. (However, chlorination of phenol at 100 ppm produced a different effect, causing a deep yellow color—presumably a quinone.)

The chlorinated 20-ppm phenol solution was divided into two portions. The first half was acidified and extracted with ether and the residue was redissolved in 500 ml of distilled water, The taste threshold was the same as it was in the solution before extraction, indicating that all the taste-producing components were recovered.

The second half of the chlorination mixture was then extracted with ether in the same way. A recovery of 19.4 mg of the mixture corresponded closely to the theoretical yield of chlorination products indicated by infrared analysis. In order to make this analysis, the residue was dissolved in 0.4 ml carbon disulfide and the spectrum was obtained using a microabsorption cell of 0.35-mm path length. The spectrum showed that 2,6-DCP; 2,4-DCP; and 2,4,6-TCP were the major components and that only very small quantities of phenol, 2-CP, and 4-CP were present. Due to its complexity the spectrum provided only an approximation of the quantitative composition.

An acceptable degree of precision was obtained by comparing the spectrum (Fig. 1, A) with that of a prepared mixture of nearly the same composition (Fig. 1, B). The composition of the products obtained by chlorinating phenol to maximum taste is:

Component	Per Cent of Product
Phenol	1–2
2-CP	2–5
4-CP	2–5
2,4-DCP	20
2,6-DCP	25
2,4,6-TCP	40–50
Carbonyl compound (oxidation product)	Clearly present

There was no trace of the components: 3-CP; 2,5-DCP; 3,4-DCP; 2,4,5-TCP; 2,3,4,5-tetrachlorophenol; pentachlorophenol; chlorohydroquinone; and 2,6-dichloroquinone.

For further proof of the presence of 2,6-DCP the mixed chlorination products were nitrated with cold, dilute nitric acid (*5*), and the presence of 2,6-dichloro–4-nitrophenol was shown by its characteristic infrared bands at 10.95 and 11.20 μ.

Taste and Odor Thresholds

After determining the composition of the chlorination products it was desirable to determine the relative contribution of each component to overall taste and odor. For this purpose taste and odor threshold concentrations were determined. Panels of 4–6 observers were used. The results are shown in Table 2. The table shows that the relative contributions to taste and odor by phenol, 4-CP, and 2,4,6-TCP are negligible. Application of the appropriate threshold data to the estimated composition indicated that 2,6-DCP contributed about 75 per cent of the total taste and 2,4-DCP and 2-CP contributed the remainder.

Previous investigators (*1*) have reported that the taste of chlorinated phenol is many times more intense than its odor and have inferred that a true taste perception was demonstrated by these investigations. This inference is an apparent contradiction of the long-established tenet of psychol-

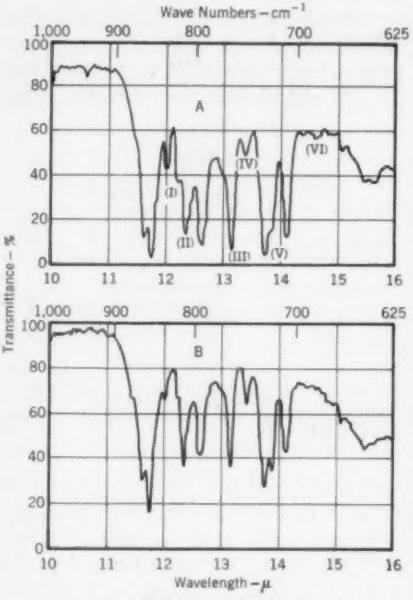


Fig. 1. Infrared Analysis of Mixed Chlorophenols

Curve A is the infrared spectrum of mixed chlorophenols obtained on ether extraction of 20 ppm phenol treated with 40 ppm chlorine at pH 8. Curve B is a known mixture of chlorophenols, made up to correspond to the estimated composition of the chlorination mixture in Curve A. The parenthesized numerals indicate the principal bands used to identify the component chlorophenols: I, 4-CP; II, 2,4-DCP; III, 2,6-DCP; IV, 2-CP; V, 2,4,6-TCP; VI, phenol.

ogy that there are only four fundamental tastes. The panel test results studied by the authors did not agree with earlier data; within the error of the method, taste and odor thresholds were equivalent. It was evident that the quality perceived was odor, not taste.

Governing Conditions

The development, absence, or disappearance of taste and odor depends upon suitable combinations of certain governing factors.

Chlorine

Ettinger and Ruchhoft (*2*) found that the addition of 4 ppm chlorine to 1 ppm phenol at pH 8 resulted in destruction of the taste, but that 7 ppm chlorine was required to produce a free residual. Paper chromatography was no longer useful under these conditions but ultraviolet spectrophotometry provided an insight into the nature of the products resulting from increased chlorination. Figure 2 shows the ultraviolet spectra obtained by chlorinating 1 ppm phenol with different amounts of chlorine at pH 8. This figure shows the disappearance of aromatic characteristics with increasing chlorine dosage. The spectrum of the solution obtained by chlorinating 1 ppm phenol with 4 ppm chlorine is typically aromatic. The 7-ppm chlorine curve shows great changes; the aromatic bands still present are much weaker compared with the 4-ppm curve. The 10-ppm curve shows no aromatic characteristics at all, indicating that the ultraviolet-absorbing aromatic ring has been completely replaced by non–ultraviolet-absorbing products.

pH

Typical development of chlorophenolic taste does not occur at less than pH 7.0. The optimum pH value is 8.0 and this value is conveniently attained with a sodium bicarbonate buffer. To demonstrate this a series of solutions containing 10 mg phenol in 500 ml of the appropriate buffer solution were treated with 20 mg chlorine. Chlorine residual was determined after 2 and 20 hr. The phenolic chlorination products were then extracted and identified by the infrared spectra. The results are given in Table 3. Negligible chlorination occurred at pH 6.0; at pH 8.0 and higher the reaction products and taste thresholds were virtually identical. However, the higher chlorine residuals at pH 9.0 and 10.0 indicate that the maximum rate of chlorination occurs at pH 8.0.

TABLE 2

*Taste and Odor Threshold Concentrations**

Component	Geometric Mean Thresholds *ppb*	
	Taste	Odor
Phenol	>1,000	>1,000
2-CP	4	2
4-CP	>1,000	250
2,4-DCP	8	2
2,6-DCP	2	3
2,4,6-TCP	>1,000	>1,000

*All tests were made at room temperature, about 25° C.

Ammonia

It is known that the presence of ammonia in the phenol solution inhibits the formation of the chlorophenolic taste, probably by consuming the chlo-

rine in the formation of the chloramines (*6*). The course of reaction under these conditions was also followed by the use of infrared spectrometry and paper chromatography.

For the infrared, 1 liter of chlorine-demand-free water containing 10 mg phenol and 13 mg ammonia, plus a bicarbonate buffer, was treated with 30 mg chlorine. After 18 hr any residual chlorine was destroyed with thiosulfate and the organic products were recovered by ether extraction. The infrared spectrum showed that the extract consisted almost entirely of unreacted phenol. An identical mixture was allowed to react for 5½ days and then was processed in the same way. Its infrared spectrum showed the presence of significant amounts of 2,4- and 2,6-DCP. An aliquot of the 5½-day sample had the typical chlorophenolic taste when diluted to 10 ppb.

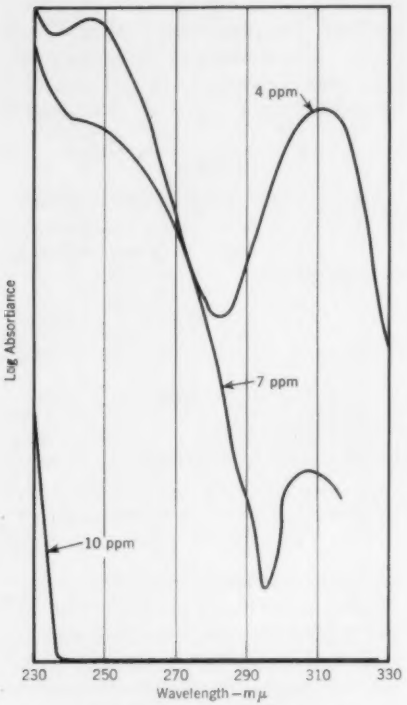


Fig. 2. Reaction of Phenol With Excess Chlorine

These ultraviolet spectra were obtained after reacting 1 ppm phenol overnight with 4, 7, and 10 ppm chlorine at pH 8 after the mixtures had reacted overnight. No values are shown for the vertical scale because this is an optical density scale, the curves were shifted to keep them from coinciding, and the numbers are, therefore, unimportant.

Ammonia and pH

The combined effect of ammonia and pH on the rate of chlorination was studied, using the appearance of 2,6-DCP on paper chromatograms as a measure of phenol chlorination. Three appropriately buffered solutions were prepared, each containing 1 ppm phenol, 7 ppm chlorine, and 3 ppm ammonia. Aliquots were withdrawn periodically and checked for 2,6-DCP by paper chromatography. Phenol was present in all cases but 2,6-DCP formed slowly at pH 9, slightly faster at pH 8, and not at all at pH 6. After 5 days residual chlorine was still present in all three solutions.

The results indicate that the same course of chlorination (Fig. 3) which results in products of intense taste occurs in the presence of ammonia, but much more slowly. Under suitable conditions this phenomenon may result in a "medicinal" taste which will be apparent to the water consumer even if it is not detectable at the water plant.

Experimental Procedure

The authors believe that it will be helpful to discuss some of the methods and ingredients used in the study of

chlorophenolic taste and odor described in this article.

Reagents. The phenol used was an analytical reagent grade. All chlorophenols were purified laboratory reagents. Ordinary 2,4-DCP contains substantial quantities of 2,6-DCP (*10*); however, the sample used for taste determination showed no trace of this impurity when analyzed by paper chromatography. Chlorine water was prepared by passing the gas into distilled water until a concentration of 1,000–1,500 ppm was obtained. This stock solution was stored in the refrigerator. Working portions were removed weekly, at which time the chlorine content was titrated with thiosulfate. Under these conditions chlorine loss was negligible.

Taste threshold (*11*). A series of dilutions of the test solution was made up in carbon-filtered tap water at room temperature. Since previous rough trials had established an approximate threshold the series was designed to include several samples below the estimated threshold, with at least one blank in the vicinity of the threshold.

Tests began with the most dilute sample in order to avoid unnecessary fatiguing of the sense of taste. A doubtful response was considered negative and whenever a blank was miscalled all positive responses below the blank were disregarded. The geometric mean of the taste panel was established as the threshold. It is desirable that observers be familiar with the compound being tested; otherwise erratic results may be obtained.

Paper chromatography (*12*). The aqueous sample, at room temperature and with excess chlorine destroyed with sodium thiosulfate, was brought to a pH between 9 and 10. A few milligrams of solid diazotized sulfanilic acid (*13*) were added and dissolved by shaking. Coupling was allowed to proceed for the required length of time, and then was halted by acidifying with concentrated HCl until the pH was less than 2.5. The dye was extracted twice with *n*-butanol (15 ml per 100 ml of solution) and the combined extracts were evaporated to dryness on a steam bath with the aid of an air stream. The residue was dissolved in a few drops of methanol and spotted on paper * which had been previously saturated with a 2 per cent sodium carbonate solution and air-dried before the spotting. The paper was equilibrated for 2 or 3 hr in the chamber and

TABLE 3

Effect of pH on Chlorophenolic Products

pH	Chlorine Residual—*ppm*		Components Detected
	2 hr	20 hr	
6.0	<0.05	<0.05	phenol; traces of 2-CP and 4-CP
8.0	<0.05	<0.05	2,4,6-TCP; much 2,4- and 2,6-DCP; traces of phenol, 2-CP, and 4-CP
9.0	0.15–0.20	<0.05	same as for pH 8.0, except less 2,4,6-TCP
10.0	0.50	0.10–0.15	same as for pH 9.0

* "Whatman No. 1," manufactured by H. Reeve Angel & Co., Inc., New York.

the chromatogram developed with a secondary butanol 2 per cent sodium carbonate system overnight, or longer. Development at a constant temperature between 20 and 25°C is desirable. Ordinarily, samples were divided into two portions which were allowed to couple for 2 min and 20 min, respectively, and were spotted separately. A 2,6-DCP component separates easily from phenol if it is run overnight, but 2-CP separates much more slowly. In some cases it is necessary to let the developing solvent run off the bottom of the paper until satisfactory separation has been achieved.

Small quantities of the solid diazonium salt have remained stable for months if stored in a refrigerator. Although para chloro compounds can couple with diazonium salts under the conditions of coupling and extraction employed in this study the dyes formed from 4-CP and 2,4-DCP could not be detected.

Chlorination. The required amounts of buffer and 1,000-ppm phenol solution were added to chlorine-demand-free water (*11*), followed by the calculated amount of chlorine water. The mixture was allowed to stand on the laboratory bench at room temperature and out of direct sunlight for 18–20 hr, except when other procedures were designated. Residual chlorine concentration and pH were checked at intervals. A phenol concentration of 1 ppm was used for chromatographic studies and 20 ppm for extraction-infrared procedures. Phosphate and borate buffers (Clark and Lubs) were used in the study of pH effects.

Ether extraction (*11*). A 500-ml portion of the chlorination mixture (after removal of excess chlorine, if any) was acidified to pH 2.5 with concentrated phosphoric acid and extracted with three 100–125-ml portions of ether. After drying over sodium sulfate, most of the ether was allowed to boil off through a 12-in. Vigreaux column. Residual ether was removed by evaporation just to dryness at room temperature with an air current.

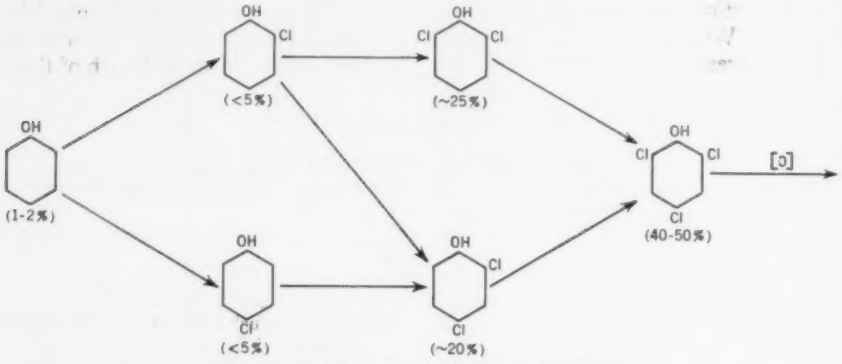


Fig. 3. Course of Chlorination of Phenol

Course of chlorination of a 20 ppm phenol solution reacted with 40 ppm chlorine, at pH 8. The parenthesized figures refer to the approximate amounts present after 18 hr.

Discussion and Conclusions

The chlorination of phenol proceeds by progressive substitution of available ortho and para positions (Fig. 3). Several taste-producing substances and other relatively nontaste-producing ones comprise the mixture of chlorination products. Earlier efforts failed to establish the identity of the products from the molar ratio of chlorine to phenol because of the number of concurrent and consecutive reactions which take place, involving extremely complex kinetic relationships. These kinetic relationships are influenced by the usual factors of concentration and temperature, and by pH and ammonia concentration. Certain combinations of these factors may prevent or retard the detectable onset of the chlorination reaction. These combinations are probably the cause of some inconsistent observations made on polluted streams containing both phenol and ammonia (*7*).

Comparatively little information on the kinetics of chlorination of dilute phenol solutions is available in the literature. Soper and Smith (*8*) have studied the reaction in neutral and in basic media at concentrations of the order of $10^{-3}M$ and have found kinetics depending on concentrations of phenoxide ion and undissociated hypochlorous acid which are the reactive species.

$$\frac{-d[HOCl]}{dt} = k\left[\text{C}_6\text{H}_5\text{O}^-\right][HOCl]$$

This equation agrees with the observation that as pH increases from near-neutrality the rate of reaction increases to a maximum and then decreases.

According to Soper and Smith, molecular chlorine is the most probable chlorinating agent under acid conditions and is produced in the equilibrium:

$$HOCl + HCl \rightleftarrows Cl_2 + H_2O$$

De la Mare, Ketley, and Vernon (*9*) reached the same conclusion about the significance of molecular chlorine at low pH. According to their conclusions the phenol would also then react in its un-ionized form. Therefore, the mechanism of chlorination would be quite different from what it would be under alkaline conditions. As a consequence not only the reaction rate but also the proportions of chlorination isomers produced might differ markedly according to the pH.

The mechanism of the reaction of chloramine with phenol has not been investigated. It is not known whether chloramine itself is the chlorinating agent or whether it slowly liberates HOCl or Cl_2 by hydrolysis to effect the chlorination. Either mechanism could account for the fact that chlorophenols are produced very slowly and that the retardation of chlorophenolic taste in the presence of ammonia is a kinetic phenomenon.

Until more clearly applicable kinetic data are available certain assumptions may be made on the basis of the foregoing as to development of taste during the water utility chlorination process:

1. Strong-tasting chlorophenols are produced whenever phenol is chlorinated, even at minimal concentration. This fact is a corollary of the finding that phenol is chlorinated by a process which starts with the pure compound, in itself relatively tasteless, and proceeds through strong-tasting intermediates to tasteless end products.

2. Chlorophenolic taste is apparent to the person testing (the point of interest to the water industry) only when the water is consumed within that time interval during which the kinetics of the system have resulted in production of 2,6- and 2,4-DCP and 2-CP in amounts in excess of their combined threshold value.

3. The factors affecting the speed of the reaction and, therefore, the time of onset and the duration of the taste period are the concentrations of the reacting species and the temperature. Concentrations of the reacting species will be affected by such factors as pH and the presence of ammonia or other substances offering competition for available chlorine.

Acknowledgment

The purified chlorophenols used as laboratory reagents in this study were supplied by Dow Chemical Co., Midland, Mich.

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Value and Limitations of Chlorine Residuals in Distribution Systems

Panel Discussion

A panel discussion presented on Apr. 22, 1958, at the Annual Conference, Dallas, Tex.

Introduction—*Harry A. Faber*

An introductory statement by Harry A. Faber, Research Coordinator, Eng. Resources Program, Div. of San. Eng. Services, USPHS, Washington, D.C.

IN water purification, as in all technical fields, it is important to stop occasionally in order to take a careful look at the progress which has been made. There is a present need to examine the value and limitations of chlorine residuals in distribution systems. The need derives from the fact that the National Academy of Sciences-National Research Council (NAS-NRC) recently has issued a report (see last article of panel) reviewing present practices, basic considerations, and residual chlorine as a warning device. The report ends with a statement of the opinion of the NAS-NRC on the desirability of universal standards for application of residual chlorine in distribution systems.

Principles

The report of the NAS-NRC presents a sensible, philosophical discussion of basic principles in water treatment practices. Although the report clearly states that its recommendations apply only to the military services, it must be recognized that the principles discussed apply with equal force to public water supplies. The report and its conclusions will, accordingly, be considered to have implications of wide general interest.

The question naturally arises: do present water treatment practices agree with principles? Certainly it can be agreed that in public water supplies there is a wide variation of circumstances encountered and the best policy to follow with regard to maintaining chlorine residuals is "to decide what should be done only after all the factors pertinent to a particular local situation or type of operation have been carefully reviewed" (*page 232*).

In principle, the author would agree also with the recommendation that the maintenance of residual chlorine not be considered "a satisfactory substitute for good design, construction, and supervision of a water distribution system" (*page 232–33*). To be realistic, however, it must be admitted that many water distribution systems—and water treatment plants—are far from "good" in design, construction, and supervision. Until all of these factors are "good" the maintenance of resid-

ual chlorine in the distribution system does provide at least a substantial degree of water safety.

Practice

The other articles of this panel present practical experience concerning the value and limitations of chlorine residuals in water distribution systems. Most important, the experience reported reveals an intelligent and purposeful application of chlorine residuals. Water utility officials can exhibit pride in the results accomplished.

"Water of the highest bacteriological quality" is what John Baylis has long set as a goal (*1*). He has pointed out that no one has proved that bacteria in *any* form are a desirable or necessary constituent of water. As a motto, he proposed: "We are producing a safe water today; it will be still better tomorrow." This motto can well provide the basic reason for careful consideration of the value and limitations of residual chlorine in finished water.

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—— Chicago—*John R. Baylis and Nicholas H. Kuehn Jr.* ——

A paper presented by John R. Baylis, Engr. of Water Purif., and Nicholas H. Kuehn Jr., Chief San. Engr., Water Purif. Div., both of the Dept. of Water & Sewers, Chicago.

In 1900 there was, as such, practically no chlorination of water; by 1910 only a few waters were being chlorinated and the amount added usually was in low dosages. During the period of 1910–20 chlorination was started on most of the remaining polluted waters, generally in low concentrations. Water chlorination has greatly progressed since Wolman and Enslow, in 1919, recommended that water be chlorinated to the extent that chlorine would be left in it after treatment (*1*). Prior to this most of these operating chlorination plants were careful to see that the water contained little or no residual chlorine when it reached the consumer.

Chlorine Increase

The Wolman and Enslow article (*1*) marked the beginning of increased dosages of chlorine to produce more effective sterilization of polluted waters. These dosages, however, were modest compared to the amounts now being used. To illustrate: a large city added 0.36–0.72 ppm chlorine from 1920 to 1928 and is now adding 1.80–2.40 ppm, with no increase in pollution of the raw water. The average amount of chlorine added to Chicago water was 0.41 ppm in 1928 and 1.22 ppm in 1957. Bacteriological results were pronounced good in 1928.

The authors frankly do not know whether the increase in chlorine dosage has prevented one more case of waterborne illness in Chicago than a lower dosage would have, but they are of the opinion that it has. There is not much evidence that the high chlorine residuals being maintained in the distribution system are affecting the pipes.

Soon after 1919 public health officials demanded that water be treated

so that there would be residual chlorine in the water long enough for effective sterilization. Low-dosage chlorination prevailed for all but the most highly polluted water until after 1930, however. Not many officials thought of maintaining residual chlorine in the water throughout the distribution system. Public health officials did not make this a requirement, particularly in cities where the bacteriological quality of the treated water was good. In 1930 many public health officials thought that perfection in chlorination had been reached and that there would be no increase in chlorine dosages. A greater realization of the danger of water in distribution systems becoming contaminated through faulty plumbing and cross connections to polluted supplies changed this opinion.

Chlorine-Ammonia Treatment

A few years prior to 1930 ammonia began to be used in a few water supplies to lessen chlorinous taste, particularly in water containing phenol. This meant that water could be treated with a considerable amount of chlorine and still be delivered to the consumer without chlorinous taste. The use of ammonia soon became common practice, particularly in water filtration plants. In the revision of water quality standards by the USPHS in 1942 emphasis was placed on samples of water collected from the distribution system. This caused increased effort to maintain residual chlorine throughout the distribution system because often in areas without residual chlorine there were increases in the bacterial content of the water. With a chlorine-ammonia residual it is possible to extend the zone of residual chlorine almost to the extremities of the system without producing an objectionable chlorinous taste.

The ammonia treatment is particularly adapted to filtration plants in which several hours are required for the water to pass through the plant. Polluted water with a high chlorine absorption can be treated with a larger amount of chlorine in the first part of the plant and then ammonia may be added after filtration to convert the free residual to a combined one so that it may be maintained for a longer time. By pretreatment advantage is taken of the high oxidizing and disinfecting property of free chlorine. If ammonia then is added to the filtered water, residual chlorine can be maintained throughout the distribution system to guard against possible contamination.

Water that is passed through the South District filtration plant in Chicago is treated in this manner. There is good disinfection even in the worst pollution periods and no chlorinous taste in the water.

Chicago Chlorination Practice

In the Central and North water districts of Chicago chlorination is applied at the pumping stations. A filtration plant is under construction and when it is completed chlorination will be applied there. Chlorine only can be used for these two districts now because the closest consumers are only a few minutes away from the pumping station. After the filtration plant is completed, probably in 1961, the treatment contemplated will be the same as for the South District plant.

The Chicago water utility attempts to maintain residual chlorine in the water of these districts substantially throughout the distribution system. Most of

the water samples collected in the area contain at least a small amount of residual chlorine. To accomplish this, the residuals immediately after chlorination at the pumping stations must be high. The average chlorine dosages and residuals for the three Chicago water districts are given in Table 1.

Chlorine is applied to the water at the eight pumping stations by employees of the operating division. The water purification division maintains close supervision of the chlorine dosage requirements at these pumping stations through two control stations.

TABLE 1

Chlorine Applied and Residuals Recorded in Chicago Water—1957

Water District	Chlorine—*ppm*			
	Amount Added		Residuals Recorded	
	Avg.	Max.	Pumping Stations	Distribution System
South	1.22	2.63	0.68*	0.41*
Central	1.23	2.16	0.90	0.46
North	1.20	1.68	0.91	0.48

* Ammonia-treated water.

Sanitary engineers are on duty all the time at these stations. Tests are made hourly, and occasionally more often, to determine the amount of chlorine treatment necessary. This includes determination of the 5-, 10-, and 30-min chlorine demand.

Under normal quality conditions enough chlorine is added to maintain not less than 0.48 ppm residual chlorine 30 min after treatment. For this reason residuals at the pumping stations immediately after chlorination are considerably more than 0.48 ppm, as is shown by Table 1. The water, after chlorination, is tested hourly with an amperometric titrator for residual chlorine to determine the exact amount of free and combined residual chlorine at the pumping stations where the control stations are located. Attendants at the pumping stations in the Central and North water districts make residual chlorine tests hourly by the orthotolidine method.

South District

The water of the South District is chlorinated and ammoniated at the South District filtration plant. Under normal conditions enough chlorine is added to the water in the mixing basins to maintain a slight residual in the filter effluent water. When conditions are normal 0.48 ppm of prechlorination is sufficient. During periods of high pollution the prechlorination may be more extensive, occasionally going to more than 2.40 ppm for short periods. Additional chlorine, and the ammonia, are added in the filtered-water header as the water flows to the main filtered-water storage reservoirs. Enough chlorine is added to produce a chlorine residual of 0.60 ppm in the outlet water.

Seven residual chlorine recorders are located in the filtration plant and there is one recorder each in two of the three South District high-service pumping stations, one 8.7 mi from the filtration plant and the other 10.2 mi from the plant. A 30-mil gal storage reservoir, which is used 5–6 months per year, is located at a third South District station, also 10.2 mi from the plant. With daily use of water from the reservoir and refilling at night no difficulty has been experienced in maintaining some combined chlorine residual in the reservoir water. Mixing this water with water pumped directly

from the supply tunnel residual is maintained constantly in the distribution system of this station. Residual chlorine, as chlorine ammonia, in the water at these three stations averages 0.36–0.60 ppm.

Sampling and Recording

Water samples for bacteriological tests are collected daily at 38 sampling points throughout the distribution system. Twenty-six of these points are in the Central and North water districts and twelve are in the South District. Each time a sample is collected the water sampler, with an orthotolidine kit, makes a residual chlorine test of the water. The number of samples collected in the three water districts amounted to 5,151 in 1957—a large number for Chicago.

A further check on the chlorination in the Central and North districts is the use of residual chlorine recorders at each of the pumping stations. These recorders are set to operate an alarm when the residual chlorine falls below 0.48 ppm. Once, when one of the charts at a pumping station showed interruption in the normal chlorination for a few minutes, the alarm system gave warning of low residual and the chlorine machines were immediately adjusted to give proper dosage.

Two residual chlorine recorders are located in the distribution system. The alarms are set to give warning if the residual goes below 0.24 ppm. This is reported to the control station of the affected area so that remedial steps may be taken.

The residual chlorine concentration in the water at established distribution sampling points varies from 0.24 to 0.60 ppm. These values, obviously depend on the initial quality of the water, time of flow, and local conditions. During times of high chlorine absorption, emergencies, and other unusual conditions in the system the control limits may be increased as an added safeguard for the water supply. Consequently, the residual chlorine concentrations in the distribution may also increase.

Value and Limitations

If water under pressure could be maintained in all water piping all of the time the necessity for maintaining the chlorine residual throughout the system would not be so great. Anyone engaged in the maintenance of a water utility, however, is fully aware that constant pressure is not possible. When a main breaks in the street at least a section of the piping system is without water. A break in a large feeder main may lower the water pressure to a point where there could be a negative head on part of the piping system. In addition to the possibility of contamination at the break every leak in the pipes or in the ground, even though quite small, may become a potential source of pollution. No piping system can be entirely free from leaks.

Regardless of the warning given to the public not to use water in any way that may cause contamination, apparently no faucet can be made to which a few persons cannot find a way to attach a hose. Even if no defective plumbing were to be installed in the future it would still be many years before all dangerous water outlets could be eliminated. The sanitary engineer has to take conditions as they are in a water system and apply treatment that insures greatest safety to the water. Maintenance of residual chlorine in the water throughout the system generally is the only safeguard

that may be used under existing conditions in many cities.

In that portion of Chicago not supplied with filtered water microorganisms accumulate in the bottom of water mains when the flow is slow. Ample proof of this statement is that occasionally water mains are found to contain 1 in. or more of sediment.

Fig. 1. Tubercles in Brass Pipe

This is part of a section of 1- or 1½-in. brass pipe. Tubercles penetrated the wall of the pipe and caused leakage. Residual chlorine was probably partly responsible for this condition, but there is no specific proof of this.

Decaying organic matter is food for bacteria, and bacteria in large numbers often are found in water mains beyond the limit of residual chlorine.

The main limitation on the amount of residual chlorine that may be maintained in a distribution system is taste. Although there is some evidence of increased corrosion of the water pipes by high residual chlorine the amounts generally used have no appreciable effect on iron pipe.

Residual chlorine appears to increase the corrosion of brass pipe, particularly in hot-water systems. Figure 1 shows a section of brass pipe with brass tubercles. The pipe was removed because some of the tubercles had penetrated the wall of the pipe and caused leakage. The evidence points strongly to residual chlorine being the main cause, but there is no specific proof.

[EDITOR'S NOTE: Experiments, reported by the *Journal of the Institu-*

tion of Water Engineers (London), vol. 6, p. 65 (1952), to determine the effect of chlorination on the corrosion of brass pipe led to the following conclusions:

[1. The corrosive action of . . . tap water at high pressure and velocity on both cast brass (B.S. 1026) and hot-stamping brass (B.S. 218) is greatly accelerated by the presence of free dissolved chlorine in amounts up to 1 ppm.

[2. Under identical conditions of test, and using . . . tap water containing 1 ppm free chlorine, cast brass and B.S. 218 hot-stamping brass undergo similar losses in weight, but the attack on the B.S. 218 is generally smooth and even, whereas that on the cast brass takes the more damaging form of irregular pitting.

[3. The addition of 1 per cent tin to B.S. 218 does not confer any increased resistance to attack by dissolved chlorine under these conditions. The results . . . suggest, however, that the presence of aluminum may be beneficial.]

Reference

1. Wolman, Abel & Enslow, L. H. Chlorine Absorption and the Chlorination of Water. *J. Ind. Eng. Chem.*, 2 (Mar. 1919).

Indianapolis, Ind.—*Marshall P. Crabill*

A paper presented by Marshall P. Crabill, Vice-Pres. of Operations, Indianapolis Water Co., Indianapolis, Ind.

The value of a chlorine residual in a distribution system is related to the characteristics of the water to which the chlorine is added. The characteristics of a raw water determine the type and range of disinfection required in the treatment plant.

The level of the residual maintained in the distribution system may be dictated by the completeness of the plant treatment or it may be established by other considerations of value.

Effects of Residual Loss

In Indianapolis chlorine residuals, regardless of their type, cannot be maintained throughout the entire system all year. When water temperatures are at their highest chlorine residuals do not reach the extremities of the system. In some places where they normally approach the extremities higher water temperatures cause them to recede. The magnitude of the residuals can be increased by a corresponding increase in the residuals leaving the treatment plant; however, the plant residuals cannot be increased sufficiently to extend them to the ends of the distribution system.

The finished water leaving the treatment plant will, with few exceptions, have no growth on 37°C plates and no coliform bacteria. In spite of satisfactory plant results high 37°C-plate counts are made and coliform are recovered at some points in the system when chlorine residuals are lost. Following the recovery of the normal chlorine residual the plate counts and gas formers return to the level preceding residual loss. Table 2 shows the results obtained at sampling station No. 49, which is 6.5 mi from the treatment plant. No coliform bacteria were detected during the testing period.

Supplemental Chlorination

At station No. 49 chlorine residuals are normally recovered from the application at the treatment plant. However, when the residual is substantially lost the plate counts and gas former levels show a decided increase. Sup-

TABLE 2

Plate-Count and Gas-Former Levels at Station No. 49—January–December

Month	Level of Chlorine Residual *ppm*	Average 37°C Plate Count	Gas-Former Level
January	0.44	2	0
February	0.38	2	0
March	0.35	2	0
April	0.38	1	0
May	0.10	1	0
June	0.03	1	1
July	0.01	51	2
August	0.03	128	13
September	0.04	183	21
October	0.11	12	12
November	0.19	5	0
December	0.40	3	0
Average	0.21	33	4

TABLE 3

Plate-Count and Gas-Former Levels at Station No. 49—Jul. 11–Sep. 26

Date	Level of Chlorine Residual *ppm*	37°C Plate Count	Gas-Former Level
July			
11	0.00	1	0
16	0.00	1	0
19	0.00	1	0
24	0.00	110	0
29	0.00	240	0
August			
1	0.00	2	2
6	0.00	49	3
9	0.00	120	3
14*	0.08	32	0
19*	0.04	6	0
22*	0.04	12	0
27	0.00	800	5
30*	0.04	3	3
September			
5*	0.04	110	4
10*	0.04	50	0
13*	0.04	21	0
18	0.04	350	3
23	0.04	550	5
26	0.04	15	5

* Hypochlorinator in service. At all other times no supplemental chlorination was being applied.

plemental chlorination is started at station No. 49 when this occurs. Table 3 shows the operating results during the high-water-temperature months when chlorine residuals were lost.

Table 3 demonstrates an improvement in bacteriological quality at the sampling point when supplemental chlorination is applied. It is believed that further improvement would have resulted with increased residuals and that the improvement would have extended further from station No. 49 to the end of the system. This can only be proved by increasing the supplemental chlorination, but there is substantial evidence that the chlorine residual in Indianapolis should be carried throughout the system and that it has a real value. For the purpose of comparison, Table 4 shows the results at sampling station No. 52 for a comparable period of time. No supplemental chlorination was applied at station No. 52, which is 8 mi from the treatment plant.

Except for the period covered by Table 4 chlorine residuals were carried to station No. 52 from the treatment plant. The bacteriological results are inferior to results when the residual was present; these inferior results are more or less typical of those from any remote sampling station when residuals are lost during the summer months.

Summarizing the results shown in Tables 2, 3, and 4, it is concluded:

1. High-level chlorine residuals maintain a better quality of water in the distribution system than low-level residuals.

2. The quality of the distributed water is reduced when chlorine residuals are lost.

3. Supplemental chlorination when chlorine residuals are lost will improve water quality.

4. There is a definite relation be-

tween water temperature and the persistence of chlorine residuals.

These conclusions indicate a real value for maintaining chlorine residuals throughout the system.

Value and Limitations

Normal operations in Indianapolis produce a free residual chlorine through the mixing basins, settling basins, and filters. The contact time is not less than 3 hr. The free residual chlorine is converted to a combined chlorine residual after filtration. The distribution system is flushed annually, and for 3 weeks each spring and fall free residual chlorine is carried in the system. It is believed that this may be beneficial because it subjects biologic growths in the system to a more active disinfectant. In spite of what the Indianapolis water utility considers quite adequate treatment and the high degree of quality of the treatment plant effluent, those points where chlorine residuals are lost in the system produce a water of substantially lower quality. This, the author believes, is a compelling reason for maintaining chlorine residuals throughout the system.

No competent operator expects that chlorine residuals normally carried in the system will disinfect the water if gross contamination occurs. Occurrences of gross contamination are rare, but a major contamination can make itself evident by its effect on normal residuals before it is discovered in other ways. In several instances decided changes in the residual normally recovered at a sampling station have indicated that unusual occurrences were taking place in the system. On one occasion the chlorine residual normally present at a sampling point about 2 mi from the treatment plant was entirely lost while residuals at other stations both closer to and farther from the plant remained normal. An investigation disclosed that the refrigeration system in a supermarket near where the sample was collected had developed a leak and backed up into the plumbing on the premises. The trouble was located even before the manager of the supermarket was aware of it. Several coliform organisms were detected in subsequent samples. Similar situations have occurred.

TABLE 4

Plate-Count and Gas-Former Levels at Station No. 52—Jul. 2–Oct. 1

Date	Level of Chlorine Residual *ppm*	37°C Plate Count	Gas-Former Level
July			
2	0.00	16	0
9	0.08	240	0
16	0.04	22	0
23	0.04	110	0
30	0.00	120	0
August			
6	0.00	1,000	1
13	0.00	1,000	3
20	0.00	200	2
27*	0.00	10	5
September			
3	0.00	600	5
10*	0.00	425	5
17	0.00	1,000	5
24	0.04	275	5
October			
1	0.12	100	4

* On these dates a coliform bacteria level of 1 was detected.

In such instances the utility should be fully aware of conditions responsible for chemical and bacteriological changes in the distribution system. In the event of illness to the consumer or questionable water quality the utility is in a much more defensible position if such occurrences can be readily ex-

plained. The responsible superintendent should be informed of any unusual changes in the system, if it is within the limits of reasonable performance to gain such information. These experiences indicate a definite value for the chlorine residual as a trouble tracer. This value is sufficient to warrant the continuous maintenance of the residual and recording the normal residual recovered at regular sampling stations.

A few years ago a biologic infestation occurring in Indianapolis was controlled by using copper-chlorine-ammonia (*1*). The control required getting residual copper-chlorine-ammonia to the remote ends of the distribution system where the infestation was evident. The success of the treatment was due to the fact that residual copper-chlorine-ammonia could be carried to those areas where it was needed, partly because the chlorine demand of the system had been satisfied by the normal chlorine residual regularly maintained.

All of the evidence points to the value of maintaining the chlorine residual in the system. The limitations on what it can be expected to do are recognized but the advantages seem to be a compelling reason for continuing system residuals.

Reference

1. CRABILL, M. P. Biologic Infestation at Indianapolis. *Jour. AWWA,* **48**:269 (Mar. 1956).

El Paso, Tex.—*Elwood J. Umbenhauer*

A paper presented by Elwood J. Umbenhauer, Supt., Munic. Water & Sewer System, El Paso, Tex.

A discussion of the value and limitations of chlorine residuals in any particular water or water system should be on the basis of:

1. Will it produce a safer water?
2. Does it reduce customer complaints?
3. Is its use economical?

From experience with the use of high free chlorine residuals in El Paso, Tex., these three questions should be answered in the affirmative. This is true even if there are unusual conditions present. These unusual conditions may include mixing of water from different sources in the distribution system and reservoirs, long distribution mains, or considerable detention time in reservoirs.

Distribution System

The El Paso distribution system could be visualized as similar to the letter "w." Each stem is about 10–12 mi long and the system varies in width from 1 to 6 mi. In the first loop is Mount Franklin, a part of the Rocky Mountains. Mount Franklin divides part of the city, forming a wall more than ¾ mi high in places. In the other loop of the system is a man-made obstacle consisting of US Air Force, Army, and guided missile installations, comparable to a fair-sized city but separated from El Paso as far as water distribution lines are concerned. Further confining the distribution system are the presences of New Mexico to the north and west, Ciudad Juarez, Mexico, to the south, and the Paso del Norte to the southwest.

The requirements of about 37,000 water-service customers have reached 60 mgd on peak summer days but drop to as little as 15 mgd on minimum days. The average pumpage is

somewhat more than 27 mgd. There is a wide variation in daily use and also in elevations at which the water is distributed. The distribution system extends vertically for a distance of 975 ft from the lowest service area to the top of the highest reservoir. These and other reasons, such as difficult terrain, have resulted in the establishment of ten different pressure systems on five distinct levels. The system tries to maintain pressures in a range from 40 to 125 psi at the service meters. Floating on the ten different pressure systems are seventeen covered, finished-water, elevated storage reservoirs with a total capacity of more than 80 mil gal. The largest reservoir has a capacity of 40 mil gal under one roof. This reservoir is built in the side of Mount Franklin. The large reservoir and three others are at the same elevation and have a total capacity of 58 mil gal. They float on the main part of the distribution system about 200 ft above the principal business area of El Paso.

Water is lifted from the river or wells in the lower part of El Paso and into settling basins. It is then lifted about 200 ft from the settling basins or clear wells into the first series of reservoirs. From there the water is lifted from the first series or group of reservoirs into a second set, a third, and a fourth. Until someone moves higher up the mountain the fourth set of reservoirs will be the last.

El Paso's water is lifted as many as five times through reservoirs at five different elevations. Considerable time may elapse between the original treatment and the final consumption of the water, not only because of the relatively high reservoir storage capacity but also because of the lifts.

To further complicate the picture the character of the water varies with its source. Part of the water is treated river water that varies greatly from time to time in its chemical composition and chlorine demand. Some of the wells that supply a good portion of the total supply have very little chlorine demand and others have water with high chlorine demands.

Chlorination

The first chlorination took place in El Paso several years prior to 1940. Before chlorination was started early in this century untreated river water was used. Diseases carried by river water were epidemic in the early years and deposits were left in parts of the distribution system. After this early use of river water only well water was used until 1943 when river water was again used as a part of the source of supply. The long use of untreated well water did not eliminate chlorine-combining substances inside the water mains. When chlorination was first practiced, therefore, some difficulties were experienced with reaction in the distribution lines. The first chlorine use was a chlorine-ammonia application at the wells or the river treatment plant, or both. This treatment was not sufficient to carry chlorine residuals through the reservoir system because the original application was only enough to produce 0.5 ppm combined residual chlorine. To overcome this, automatic chlorination without any ammonia addition was applied to the water leaving each reservoir.

After approximately 8 years of this practice the use of ammonia was discontinued entirely. Chlorine to produce a residual of 0.75 ppm was added to water leaving the different sources of supply. It was soon learned that many of the smaller reservoirs maintained a satisfactory residual and did not need additional booster charges

into water leaving them. Some of the largest reservoirs still required chlorine booster charges to make up for the loss of residual in storage, but to a lesser extent than formerly.

This change proved very satisfactory and, working on the assumption that if a little does good more will do better, another change was made in 1956. The free chlorine residual was increased from 0.75 to 2.0 ppm and the residuals in the far reaches of the distribution system were maintained at no less than 1.5 ppm.

The results were considerably better than anticipated. Almost all complaints from householders stopped. Experiments for a day or two with residuals of as high as 5.0 ppm in certain areas did not lead to any unusual trouble. At times it is possible with the 2.0-ppm free chlorine residual to maintain sufficient chlorine in the water in the 40-mil gal reservoir. The high free chlorine residual level has resulted in water of exceptionally good quality when tested for bacteria.

The nature and amount of the complaints received have changed. There are fewer complaints and these are now mostly from commercial establishments instead of from home owners. However, some newcomers to the area notice a taste in the water—not usually unpleasant—and there are a few people with exceptionally sensitive palates. Many of the complaints are found to be the result of the action of chlorine with various foreign substances, such as a soap scum in a careless restaurant, some types of paper or waxed cups, phenolic taste in ice caused by certain types of packages, other tastes in ice when insufficient coring has been practiced, and others. Water also sometimes has an unpleasant taste or smell when drunk after eating certain foods, such as fruit cocktail.

El Paso's experience with the use of 2.0-ppm chlorine residuals in the distribution system has, in general, been highly successful, especially from the standpoints of bacteriological safety, customer relations, and economical treatment.

Survey of Chlorine Residuals in Treatment Plants

Attmore E. Griffin

A paper presented by Attmore E. Griffin, Tech. Consultant, Div. of Tech. Services, Wallace & Tiernan Inc., Newark, N.J.

The amount of chlorine used, the type of chlorine residual produced, and the effect of the chlorine residuals maintained in distribution systems are of extreme interest to all water and public health officials. To obtain information on these subjects a questionnaire was sent to 114 municipalities and water authorities or districts. Eighty-five replies, covering 92 water treatment plants, were received early enough to analyze. A quick check of the late arrivals indicated that their inclusion would not have altered the results significantly.

Survey Treatment Plants

The survey covers treatment plants in 30 states, two Canadian provinces, and the District of Columbia. Geographical, geological, and population distribution are believed to be reasonably well balanced.

Tables 5 and 6 show the sizes and types of treatment plants represented.

TABLE 5

Size of Plants in Survey

Water Treated *mgd*	Treatment Plants	
	Number	Per Cent of Total
1–10	26	28.3
11–25	26	28.3
26–50	14	15.2
51–100	12	13.0
>100	14	15.2

Eighty-one of these plants used surface water and eleven used ground water as a source.

Inasmuch as all but one of the plants surveyed use chlorine in one way or another, and some in more than one way, it is important to learn the types of chlorine application in these plants. This is shown in Table 7.

The chlorine-ammonia process has been used for nearly 30 years in the control of tastes and odors, particularly where industrial wastes such as phenols are present in the raw water supply. Thirty-five of the treatment plants in the survey (38 per cent of the total) used the chlorine-ammonia process. The points of ammonia application of these 35 plants were: pre-ammonia, 7; postammonia, 26; pre- and postammonia, 2. (Thirty-eight per cent users of the chlorine-ammonia process is a high percentage. There are 16,747 water supplies in the United States and only about 1,000 of them, or 6 per cent, use ammonia. However, this survey applies only to plants processing 1 mgd or more of water.)

Ammoniation originally was applied at the head of the plant and, prior to chlorination, as a protection against chlorophenolic odor production. With the introduction of activated carbon in the 1930's and the perfection of the breakpoint process of chlorination in the early 1940's, ammonia application gradually shifted to post-treatment to stabilize the chlorine residual and to prevent chlorinous odors in the finished water.

Chlorine residuals have been determined by the orthotolidine method for many years. The amperometric method for determining chlorine residuals was introduced in the early 1940's. Since that time the method has been widely accepted until today more than 20 per cent of the water treatment officials questioned have adopted it as the sole method of measuring chlorine residuals (Table 8).

Practically everyone in the water field has either wondered or has been asked what the day-to-day range of chlorine dosage may be throughout the country. The figures gathered in this survey provide at least a partial answer to such questions or speculations:

Treatment	Cl_2 Applied—*ppm*		
	Min.	Max.	Avg.
Prechlorination	0.20	25.0	4.28
Postchlorination	0.02	12.0	1.30

It may seem extreme to add 25 ppm chlorine to water used for domestic purposes but such a dosage is not at

TABLE 6

Types of Treatment Used by Plants in Survey

Type of Treatment	Treatment Plants	
	Number	Per Cent of Total
Coagulation and filtration	56	60.9
Slow sand filtration	1	1.1
Lime-soda softening	21	22.8
Ion-exchange softening	1	1.1
Aeration only	1	1.1
Chlorine only	12	13.0

TABLE 7

Types of Chlorine Addition in Plants in Survey

Type of Chlorination	Treatment Plants	
	Number	Per Cent of Total
Prechlorination only	23	25.0
Postchlorination only	15	16.3
Pre- and post-chlorination	54	58.7
Chlorination only*	12	13.0

* Chlorine constituted the sole treatment in these plants; therefore they could not be reported as practicing pre- or postchlorination.

all unusual, particularly along the Ohio River. Also, the all-time record chlorine dosage of 110 ppm at Ottumwa, Iowa, in 1940 still stands.

The figures presented in Table 9 are not statistically correct and should not be taken as a reflection of water utility practice as a whole. However, the figures are believed to present a true picture of the maximum chlorine residuals being maintained in the reporting plants. It is significant to note that at 30 of the 92 plants in the survey free chlorine residuals are carried to the far end of the system and that 51 plants carry chlorine-ammonia residuals to these same areas.

Conclusions From Questionnaire

Perhaps the apparent trend to carrying chlorine residuals to the far ends of the system (see Table 9) accounts, in part, for the fact that few of those answering disagreed violently with the statement in the survey questionnaire:

I have the idea that with adequate free residual chlorination a water can be produced which will not develop gas in the fermentation tubes. This, of course, means zero "coliforms." Furthermore, I believe it is possible to chlorinate the majority of waters in such a way that the broth used for bacteriological testing will neither turn turbid nor develop a scum or sediment during incubation. Do you care to comment on or challenge this statement?

Some of the answers read:

1. Agree, with reservations.
2. I used to agree but now am doubtful.
3. Yes, with reservations as to practicability.
4. Yes, provided the situation is closely controlled.
5. Data at my plants contradict both statements.
6. Probably possible but would cause tastes and is not justified.
7. Yes, in general, although certain circumstances may prevail that make it impractical.
8. Agree with entire statement.
9. Agree in relation to our water. Cannot answer for any other water.
10. With 0.5 ppm free chlorine no gas but always scum or sediment in all tubes.
11. First part I agree with, but as to second part I'm not so sure.
12. Yes to first part, but during periods of high turbidity difficult to obtain second part.
13. Probably true but doubt that such perfection is necessary. Would be useful in bacteriological warfare.
14. Yes for both if free residual is maintained throughout the treatment process.

TABLE 8

*Methods of Testing Chlorine Residuals of Plants in Survey**

Treatment Method	Treatment Plants	
	Number	Per Cent of Total
Orthotolidine	42	45.7
Amperometric titrator	20	21.7
Orthotolidine and titrator	19	20.7
Starch iodide	1	1.1

* Ten of the 92 plants in the survey used other methods, or did not reply to this question.

15. Probably correct.

16. As for the broth turning turbid, developing a scum or sediment, I cannot agree that this is necessarily significant. At any rate, it will be outmoded one of these days as more and more laboratories change to the membrane filter work.

17. Yes, in general, although certain circumstances such as presence of turbidities as low as 1 or even less often make it impractical.

The question as to the influence of the water temperature on the persistence of chlorine residuals was answered by nearly everyone to the effect that the higher the temperature the more rapidly the residuals dissipate. Several times 60°F was mentioned as being the point above or below which there is a rapid change in chlorine residual persistence.

Regarding pH there were divided opinions. Answers were less numerous than those on temperature, but the majority of those answering felt that as the pH drops the activity of chlorine increases. Such an answer was not unexpected, particularly in view of the data relating to the ionization of hypochlorite published by Moore (*1*).

The effect of chlorine residuals on the taste and odor quality of the finished water apparently is in dispute. Some replies claimed that the maintenance of any amount of residual chlorine in the distribution system definitely increases taste and odor; an equal number claimed that the maintenance of a substantial free chlorine residual reduces the incidence of tastes and odors more effectively than any other means. In some instances very heavy chlorination followed by dechlorination has proved to be the most practical and effective way to rapidly eliminate varying raw water tastes and odors.

As to the influence of the type and magnitude of chlorine residuals on the bacterial quality of the finished water there was a wide variety of answers. Most of those who answered agreed that free residual chlorine is a much more effective bactericide than combined residual and that, in general, the greater the chlorine residual the more complete the bacterial kill will be. Several reported that clear tubes at the end of the incubation period are routine at their plant. There was one outstanding exception to this. In one case it was reported that for the past 5 years it has been necessary steadily to increase the amount of applied chlorine in order to eliminate coliform organisms and that clear fermentation tubes have never been obtained. During this period there has been no measurable change in the chemical quality

TABLE 9

Chlorine Residuals Maintained by Plants in Survey

Testing Point	Number of Plants	Average Free Residual Chlorine *ppm*	Number of Plants	Average Combined Residual Chlorine *ppm*
Top of filters	39	0.87	37	0.62
Leaving plant	34	0.72	54	0.93
Balancing reservoir	19	0.39	28	0.66
End of system	30	0.18	51	0.51

of the water. The cause for this continuing demand for more chlorine is not known but is under intensive investigation by the municipality affected.

Chlorine residuals and the *C* value in distribution systems apparently have been of little concern to most operators because very little data were submitted on this subject. The overall opinion seems to indicate that the maintenance of chlorine residuals will hold the *C* value at a static point over a long period of time.

In general, the maintenance of chlorine residuals throughout the distribution system is reported to preserve the water quality as to color, turbidity, taste, and odor. Occasionally, when the chlorine residuals rise above certain critical values, "red" water results. In several treatment plants it was reported that tastes and odors in finished water containing chlorine residuals were a function of pH. In one case a rise in pH from 7.6 to 7.8 produced chlorinous odors and reducing pH to 7.6, other conditions remaining the same, eliminated the odor.

Summary

It is hoped that this article is an accurate reflection of the vast amount of material received. One thing is certain: the value of chlorine for elimination of coliform organisms from water is undisputed. The use of chlorine to eliminate all bacterial growth in lactose broth tubes apparently is a possibility but is not always practical, in spite of the fact that this ideal is routinely attained at many plants. As to tastes and odors it is generally agreed that chlorination is beneficial, although now and then circumstances arise in which chlorine increases tastes and odors. This usually results in a struggle to obtain the proper balance between coliform-organism control and esthetic qualities in the delivered water. Temperature, pH, turbidity, time of contact, type of chlorine residual, magnitude of chlorine residual, and, finally, persistence of chlorine residual in the system all play a role in elimination of bacteria with chlorine.

Acknowledgment

The author is deeply indebted to all those who took the time to answer the survey questionnaire. Without their cooperation this survey of operational chlorination would not have been possible.

Reference

1. Moore, E. W. Fundamentals of Chlorination of Sewage and Waste. *Wtr. & Sew. Wks.*, **98**:3:130 (1951).

Maintaining a Trace of Residual Chlorine in Water Distribution Systems

NAS-NRC Statement

A report prepared for the Subcommittee on Water Supply of the Committee on Sanitary Engineering and Environment of the National Academy of Sciences-National Research Council, Washington, D.C.

The question whether or not it is universally desirable, as a matter of policy, to maintain residual chlorine in water in distribution systems operated by the United States military services was presented to a committee of the National Research Council (NAS-NRC) in 1953. A statement of the conclusions reached was published Oct. 7, 1955. Subsequent comment

has indicated the need for clarification of the original statement.

Present Practice

Since the early part of the twentieth century, when chlorine came into use for disinfecting potable water, there has been discussion of the desirability of maintaining a chlorine residual in water distribution systems. The maintenance of residual chlorine as an antibody in the veins of a water system appears attractive because, under certain conditions, the residual provides some degree of protection against pathogenic organisms which might adventitiously enter the distribution pipes. During World War II the practice of maintaining or seeking to maintain residual chlorine in water in distribution systems became fairly widespread, particularly in military establishments. Since the war there has been an increase in the number of towns and cities that maintain residuals in their distribution systems.

There has been little uniformity of practice with regard to the type and amount of residual maintained. In some systems the residual has been free available chlorine and in others it has been combined available chlorine. Sometimes the residual levels are allowed to rise and fall through a wide range as the demand for water changes. Occasionally operators attempt to maintain residuals in all parts of the system, but more often they are satisfied if residuals can be found in pipes through which water is actively circulating.

Basic Considerations

One fundamental fact is central to all others in this matter: the only stable chlorine residual is that developed in a chlorine-demand-free water. The production of essentially chlorine-demand-free water, however, has no public health justification. Virtual bacteriological sterility can be achieved by chlorination of otherwise potable waters with lower concentrations than would be required for the complete satisfaction of the demand-producing substances. Therefore, in ordinary practice all waters treated to meet drinking-water standards contain minute concentrations of substances that react slowly with chlorine in dilute solution so that an initial chlorine residual tends to disappear as the water flows through the distribution system. The inner surfaces of the distribution system itself will also exert a chlorine demand, which can initially be satisfied only by prolonged and relatively heavy chlorination. In order to maintain a trace of residual chlorine in the water reaching the most distant consumer, therefore, the initial chlorine residual must be high enough to offset the demands of the water and also to supply, at the outset of the operation, the demand of the water-contact surfaces. To maintain a residual while avoiding high initial concentrations rechlorination might be applied at intervals throughout the system in a manner analogous to the use of pumping stations to offset friction losses in long pipelines.

Combined chlorine residuals can be maintained within a distribution system much more easily than can free chlorine residuals. The combined residuals, however, are such relatively weak disinfectants that it is questionable whether the two types of treatment should be considered analogous or even comparable unless the combined residuals used are 10–20 times the usual values for free residuals.

The physical and technical difficulties of maintaining residual chlorine throughout a distribution system vary

greatly, depending on the physical layout of the system. A residual level which may be maintained with relative ease in a compact distribution system with good circulation may be difficult to attain in an attenuated system. These physical differences seem to preclude the enunciation of a single standard of practice.

Residual chlorine in the concentrations routinely employed in water utility practice, will not ordinarily disinfect any sizable amount of contaminating material entering the system, though this will depend on the amount of dilution occurring at the point of contamination, on the type and concentration of residual chlorine, and on the time-of-flow interval between the point of contamination and the nearest consumer. For this reason, a very much higher than normal residual is indicated as an emergency procedure during periods when pressure in parts of the system may fall to a low or even negative value, for example, periods of unusually heavy fire draft, broken mains, floods, or extensive reconstruction or rehabilitation. Such periods of need for the high chlorine residual are as a rule relatively short, ranging from a few hours to a few days.

Chlorine as a Warning Device

It has been suggested that residual chlorine be used as a warning device. The presence of detectable residual chlorine throughout the system would signify that no entry of chlorine-consuming material had occurred. Conversely, a sharp drop in or disappearance of residual chlorine would signal immediate need for the institution of an emergency chlorination regime, with a follow-up sanitary survey to locate the portal of entry of the contamination.

The value of this suggestion depends on the type of residual maintained and is directly proportional to the frequency of the sampling, the number of sampling points, and the extent of knowledge of the normal variations in residuals at the sampling points. A program involving the use of residual chlorine in amounts which on disappearance would serve as a warning of unusual contamination would entail considerable cost. In well-designed distribution systems covered by adequate plumbing codes and competent inspection, the danger of back-siphonage and cross-connection is minimal. Even where these standards are not met, under ordinary circumstances the use of residual chlorine as a warning device is not considered necessary nor very practicable.

Conclusions

In view of the factors discussed above it is the opinion of the NAS-NRC that the establishment of a universal standard for maintaining residual chlorine in water in distribution systems is not desirable. Due to the wide variation in circumstances encountered in the different types of military installations and activities, it is the opinion of the NAS-NRC that the best policy to follow with regard to this matter is to decide what should be done only after all the factors pertinent to a particular local situation or type of operation have been carefully reviewed.

It has been noted that many water system are able continuously to distribute a safe potable water without maintaining residual chlorine in water in the distribution system. In general such systems are characterized by the excellence of their sanitary design and by the thoroughness and competence

of the sanitary control over their operation. It is recognized also that in other circumstances the most practical means of obtaining water quality that meets accepted bacteriological standards may be insistence on sufficient chlorination to maintain a safe residual level in water in the distribution system. However, the NAS-NRC does not consider maintenance of a residual a satisfactory substitute for good design, construction, and supervision of a water distribution system, nor does it feel that the presence of a residual in the system constitutes a guarantee of water potability. Routine bacteriological analysis at representative points throughout the distribution is the most significant measure of water safety.

The NAS-NRC has therefore recommended against establishment by the military services of a standard of practice calling for universal maintenance of distribution-system residuals. It has had no intention of setting up rules for civilian health agencies, or of denying that such residuals are useful under many conditions.

Coagulant Aids for Potable-Water Treatment

The USPHS Technical Advisory Committee on Coagulant Aids for Water has added the following products to the list of those which may be used for water treatment—in the concentration recommended by the manufacturer—with no adverse physiological effects on water consumers: Kelgin W, Kelcosol, Burtonite No. 78, and Hagan Coagulant Aid No. 2.

The committee's findings bear only on the health aspects of the use of such products and do not constitute an endorsement or indicate their effectiveness in the proposed use. Coagulant aids on the committee's list as of Oct. 1, 1958, are:

Manufacturer	Product	Max. Concentration Recommended by Manufacturer *ppm*
Allyn Chemical Co.	Claron	1.5
The Burtonite Co.	Burtonite No. 78	5
E. F. Drew & Co., Inc.	Drewfloc	*
Hagan Chemicals & Controls, Inc.	Coagulant Aid No. 2	1
	Coagulant Aid No. 7	0.75
	Coagulant Aid No. 11	4
	Coagulant Aid No. 18	15
Hercules Powder Co.	Carboxymethylcellulose	1
Kelco Co.	Kelgin W and Kelcosol	2
The Permutit Co.	Permutit No. 65	2
	Permutit No. 66	2
	Permutit No. 67	4
Stein, Hall & Co.	Jaguar	0.5

* 1.8 ppm alum, 0.5:10 lime.

Plant Improvements and Quality Control at Elizabeth, N.J.

James Girand

A contribution to the Journal by James Girand, Chief Engr., Elizabethtown Water Co. Consolidated, Elizabeth, N.J.

FOUNDED in 1854, Elizabethtown Water Co. Consolidated serves a large and rapidly growing industrial and residential area in central New Jersey. Many areas of the state have suffered from acute water shortages during recent years, but by forward planning and economical construction, Elizabethtown has been able to meet its customers' needs without curtailment or restriction of service.

Until recently, practically all water supplies in central New Jersey were obtained from local wells. With the rapid growth of water use, the underground supplies have been depleted and the area has been declared a critical ground water area under the state conservation laws. Well drilling has practically ceased. This means the additional supplies needed to meet the rapid growth of the area must be obtained from outside the area. The Elizabethtown system was designed to meet these needs and in the last few years has been called upon to supply not only the growth in its own franchise territory but also the growth in neighboring areas. Since 1950, the total production of the Elizabethtown system has more than doubled. At the same time, the sales to other systems have quadrupled. On peak days, over 50 per cent of the water sold by some neighboring utilities comes from Elizabethtown.

Relations with the municipally and privately owned utilities serving the neighboring areas constitute the greatest challenge to the technical management of the system. These areas have always derived their water from wells, which supply water with many desirable characteristics, such as absence of taste, odor, turbidity, and color, along with uniformly low temperature. It is well known that whenever a group of customers become accustomed to a certain type of water, they object to any change, particularly the substitution of a surface water for well water. Customers of the neighboring utilities monitor the quality of the Elizabethtown water constantly and are quick to register a vehement protest at the slightest deviation.

Sources of Supply

The Elizabethtown system obtains its raw water principally from surface sources. The early management of the company displayed foresight in selecting a location for a filter plant at the confluence of the Raritan and Millstone rivers and also near the old barge canal from the Delaware River. The filter plant, therefore, has three independent sources of water which can be used singly or in combination ac-

cording to the quality of each source at any time.

There is no storage on any of these sources and, during periods of protracted drought, the plant takes more than half the total available flow. It is expected that the storage problem will be solved soon by a bond issue which, if passed, will provide the sorely needed storage.

Another problem which has arisen over the years is that, as industrialization has occurred, industrial effluents have made up a larger and larger percentage of the stream flow. These contaminants so affect the tastes and odors that this year eight times as much activated carbon is being used as was used in 1950.

Design of Plant

The present filter plant was constructed in 1929. The plant was designed by Nicholas Hill of New York City. It consisted of a low-lift pump station, a "subsidence" basin, coagulation basins, gravity filters and a high-lift pump station. Originally, there were six filters, each with a capacity of 2 mgd.

An interesting feature of the plant is the subsidence basin. The basin has a capacity of 20 mil gal and was intended as a place where the heavy turbidity in the rivers at flood stage could be allowed to settle without coagulation. Experience proved, however, that there was little turbidity in the water at any time and that any turbidity present was actually an asset to the treatment process rather than a handicap. Consequently, the maximum benefit was not derived from this basin until recently when it was converted into a true coagulation basin (of exceptional size).

A flocculation basin and chlorine contact basin were made by means of baffles. A dividing wall was placed down the middle of the basin to facilitate rapid cleaning without taking the entire basin out of service. A general view of the plant showing the basin and dividing wall is shown in Fig. 1.

The new coagulation basin has sufficient capacity for the foreseeable future demands of the plant. The design criteria of the basin at the present flow of 50 mgd are:

Velocity	0.57 fpm
Overflow rate	374 gpd/sq ft
Detention time	8.33 hr
Outlet weir overflow rate	110,000 gpd/ft

From these figures it can be seen that the coagulation basin is substantially underloaded. The effluent is consequently of unusually high quality. As a matter of fact, it is so well treated that it fully meets the USPHS Drinking Water Standard (*1*).

Customer Complaints

During the past several years, the company management has been under increased pressure from its customers —mostly the neighboring utilities who are receiving surface water for the first time—for a uniform quality of water. The regular customers of the Elizabethtown system, who have been receiving filtered surface water at all times, are not particularly concerned with the minor variations which are characteristic of treated surface supplies. But the demand for perfection of quality has led to a continuous program of plant improvement.

The complaints received were usually related to taste and odor, although the problems of corrosion entered in. The calcium content of well

water made it practically noncorrosive, whereas the surface waters are unusually soft (about 60 ppm) and are highly corrosive. This corrosiveness does not produce the common red-water complaints, but it leaves a sediment in the distribution system, which, under peak loads, washes out, producing color and turbidity.

The first complaints were puzzling in that they did not correlate with the plant operation. For instance, a vociferous complaint would be received that chlorine was present in some isolated area. Upon investigation, it would be found that the complaint was justified. After a number of such instances, it was concluded that there must have been some temporary mechanical or human failure at the plant. The routine operations of the plant followed the standard pattern of all filter plants with certain chemical analyses, such as chlorine residual and pH, every hour and other analyses made daily or on some fixed schedule. It began to appear that something was getting by unnoticed. It was also found after a detailed check of the operating procedures that the chemical feeds might be erratic or fail to adjust properly to the chemical variations of the raw water supply. It was concluded that instrumentation and automation were the only solutions to the problem.

Illuminated Clear Well

In 1956, when the last filters were added, an illuminated clear well was constructed (Fig. 2). The water depth is about 14 ft. Submerged swimming pool lights are directed toward a white-tile sign with blue letters. This illuminated clear well has proved to be the most valuable instrument at the plant. At the 14-ft depth and with the strong lights shining from one side downward on the sign, the observer obtains a composite view of the color, turbidity, and Tyndall effect in the delivered water.

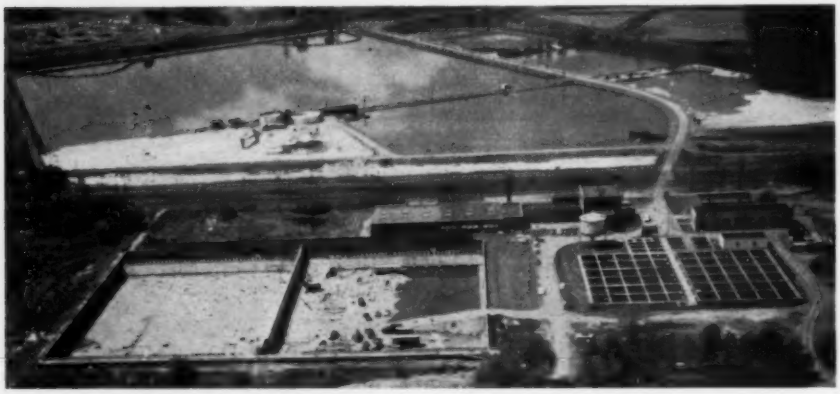


Fig. 1. Aerial View of Elizabethtown Filtration Plant

The subsidence basin, here being converted into a coagulation basin, is to the left. The lagoons in the background are used for waste disposal by a local industry.

This illuminated clear well is a hard taskmaster. Because of the depth, the slightest discoloration or turbidity is accentuated many times. For instance, a color in excess of 5 or a turbidity in excess of 1 ppm will practically obscure the sign. With the clear well as a guide, the goal of the operations is a color of less than 2 and a turbidity less than 1 ppm. The clear well is checked each hour, and it is remarkable how rapidly the quality of the water may change.

This illuminated clear well has performed so satisfactorily that it has become the major guide for the operation of the plant. The filter-washing schedule has been correlated with the appearance of the water instead of loss of head or quantity filtered. The principle of observing the quality of the filtered water has been extended throughout the plant. Experiments are being conducted to determine the best method of observing the effluent from each filter. A number of filters have been set up with 5-gal glass jars through which a strong beam of light is passed (Fig. 3.) These give a clear indication of the presence of turbidity in the effluent. Another promising device has been installed on one filter. This is a flow turbidimeter (Fig. 3) which has its indicating galvanometer mounted on the filter control table. This instrument appears to offer considerable precision in the determination of turbidity in the filter effluent.

Another important device is a viewing well (Fig. 4) consisting of a 14-ft length of 6-in. aluminum pipe, which has the same water depth as the main illuminated clear well. This viewing well has a light at the bottom and a tile sign similar to that in the large well.

Another valuable instrument is the recording flow colorimeter, which is used to obtain a continuous record of the color of the finished water. This device passes a beam of light through an 18-in. depth of water and onto a photoelectric cell. The amount of light reaching the cell is inversely proportional to the color in the water. The electric energy generated by the cell actuates a strip recorder.

To observe the quality of the water in process, two underwater periscopes have been mounted in the coagulation basin (Fig. 5). One of these periscopes is mounted at the flocculator baffle to observe the condition of the floc. The other is mounted near the chlorine baffle to observe the condition of the settled water from the basin. These underwater periscopes are particularly valuable in that they are equipped with swimming pool lights so that observations can be made at any time of the day or night. They also eliminate effects of wave action and reflections so that the observations made are always comparable.

All of these devices for making critical observations of the appearance of the water have proved invaluable in the continuing program to improve the quality.

Alum Feeding

In the process of developing better techniques for controlling the treatment of the water, much research was done in the field of chemical feeds. These studies embraced not only the proper amount of chemicals to be fed but also the proper points for their application.

Liquid alum is the coagulant used and has proved very successful. The feed is regulated by means of rotameters which are set by the operator in

Fig. 2. Illuminated Clear Well

The depth is about 14 ft. The surface line is barely visible above the sluice gate on the right.

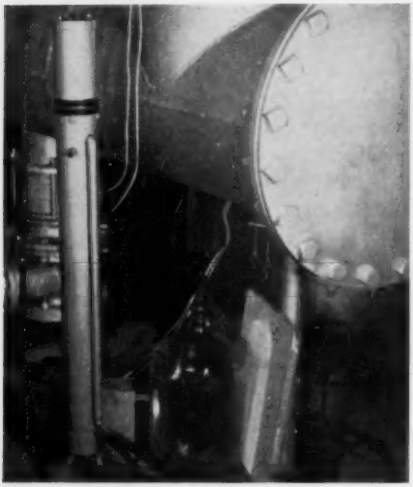


Fig. 3. Method for Checking Quality at Each Filter

A strong light beam shines through the 5-gal jar for observing turbidity. The instrument at the left is a turbidimeter, the galvanometer for which is located on the control panel of the filter.

proportion to the pumpage from the low-lift station. The quantity of alum fed is determined by the appearance of the floc as observed by the periscope in the coagulation basin. Studies were made to determine whether the alum feed could be automated by relating it to the pH of the treated water, but it was found that pH was in no way a measure of the floc formation. Success has only been achieved by visual observation of the floc formed in the basin. The liquid alum is fed into the suction well of the low-lift pumps, which serve as flash mixers.

Activated Carbon

Activated carbon is used for taste and odor control. From the public relations standpoint, this is by far the most important item of the chemical process. The customers are extremely sensitive to the slightest taste or odor. Control of the carbon feed, therefore, must be maintained with a maximum of reliability.

Hot-Water Fountains

Control is maintained by laboratory threshold odor tests on a routine basis. The most important control is three hot-water (140F°) fountains, which furnish continuous flowing samples from the inlet of the coagulation basin, the outlet of the coagulation basin, and the delivered water (Fig. 6). The operators smell or taste the water from these hot-water fountains every hour. If there is a change in the quality of river water or a failure of the carbon feeders, an immediate warning is given and the condition can be corrected.

The carbon is fed into the suction of the low-lift pumps, which act as flash mixers, before it enters the coagulation basin. No chlorine is added at this

point in the plant. Research demonstrated that chlorine and carbon should not be added at the same point, as they react with each other so that about 40 per cent of the value of each is lost. The chlorine is added near the outlet of the coagulation basin, by which time the carbon has settled out with the floc.

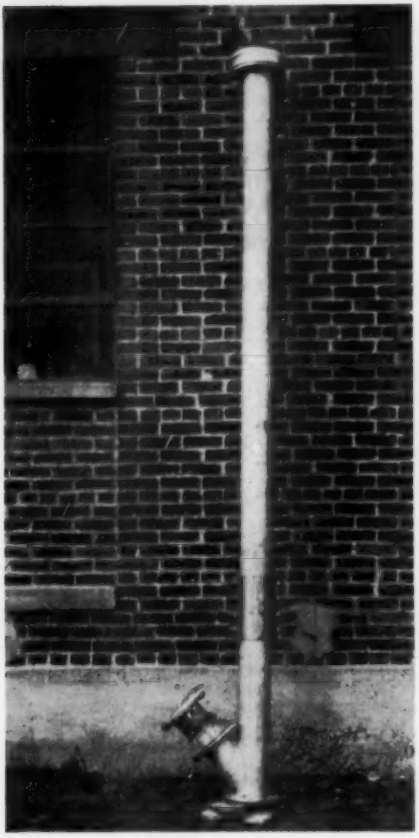


Fig. 4. Viewing Well for Water Quality Checks

This viewing well is a smaller model of the one shown in Fig. 2. It is also 14 ft deep and has an illuminated tile sign at the bottom.

Chlorine

The accurate feeding of chlorine at the plant proved to be one of the most difficult problems. A central chlorine room with seven chlorinators has been set up with plastic pipe manifolds, which permit the application of chlorine at any desired point. A prechlorination dose can be fed at the inlet of the basin, at two locations within the basin, or at the outlet of the basin before the filters. Postchlorination is at the suction wells of the high-lift pumps.

The prechlorination feed was the most difficult to solve. Chlorine residual recorders were installed at the outlet of the coagulation basin and on the delivered water. In the course of the research, it was found that the chlorine demand of the raw water from the rivers changed from hour to hour. This is apparently due to temperature, sunlight, and growth of organisms. The chlorine demand ranged from 2.98 ppm to 5.39 ppm within a few hours. All of this was unsuspected until the recording instruments were installed.

It was found impractical to prechlorinate at the inlet of the basin, because of interaction of the chlorine with the activated carbon and because the long detention time in the basin would allow the chlorine to evaporate completely, leaving no residual. As the water from the coagulation basin passes immediately to the filters, this posed a problem as to where the chlorine could be fed. It was decided to experiment with a chlorine contact chamber formed by a baffle near the outlet end of the basin. The chlorine solution was distributed by orifices in a plastic pipe located on top of this baffle (Fig. 7). There was considerable discussion as to whether this method of feeding

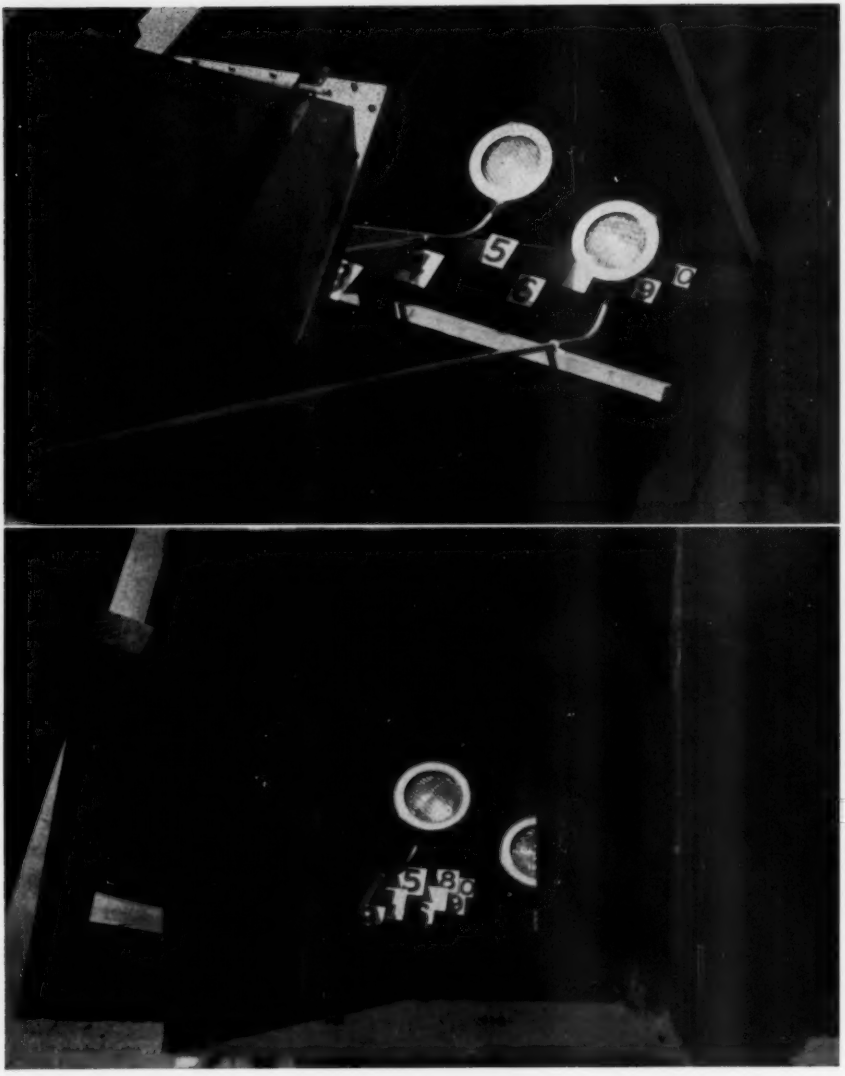


Fig. 5. Underwater Periscope in Coagulation Basin

This periscope at the flocculator baffle provides a means for observing floc formation and water clarity at the inlet to the basin. Lights make observations possible at all times. Numbers indicate water depth. The lower photograph was taken looking into the periscope.

would be effective or whether there would be short circuiting and dead spots where the chlorine did not diffuse. To provide a factual answer, an extensive test was made when the chlorine was first applied. Personnel were stationed in boats in the chlorine contact area, and a great many samples were taken on a systematic basis. It was found that the chlorine was such a highly active substance that it dispersed with extreme rapidity. The detention time in this chlorine contact chamber is about 1½ hr; however, it was found that, within 20 min after the chlorinator was started, the chlorine had uniformly dispersed throughout the chlorine contact basin. There has never been any evidence of short circuiting or dead spots.

During the past year, an additional chlorine distribution header was placed in the basin about 40 ft ahead of the chlorine baffle. The purpose of this pipe is to provide a point where superchlorination can be added with dechlorination by means of sulfur dioxide through the chlorine line on top of the baffle. To date, it has not been necessary to use this process, but it appears that it would function satisfactorily.

Chlorine Feed Regulation

The feeding of the chlorine in the big basin was a complete success, but in the regulation of this feed almost insurmountable obstacles were encountered. It was almost impossible to maintain a reasonably uniform residual. Months of study were required before the causes were fully known and an accurate control could be perfected. It was found the hitherto undiscovered variation in the chlorine demand of the raw water was the most difficult problem. It could only be overcome by varying the chlorine feed from time to time, more or less on a judgment basis. It was also found that serious deviations were produced by any change in water level in the basin, which could be caused either by starting or stopping the low-lift pumps or by variations in the flow taken out of the basin during filter washing or changes in the filter flows. An interesting discovery was that when the water level in the basin was maintained at a fixed elevation by

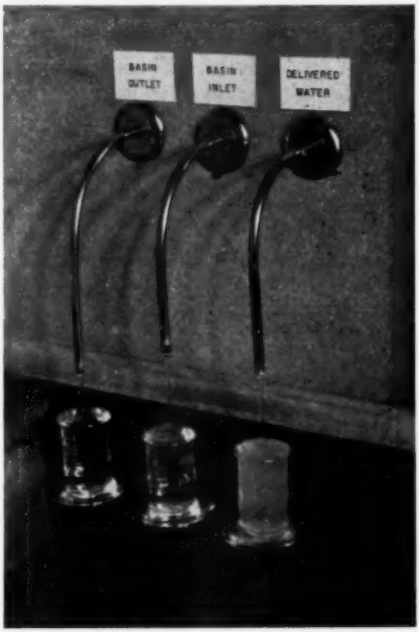


Fig. 6. Hot-Water Fountains in Laboratory

Hourly sampling of these fountains, which provides constant samples of delivered water and water at the basin inlet and outlet, provides a check on tastes and odors.

spilling a small amount over an overflow weir, the chlorine results were remarkably improved. There was, however, no justification for wasting this water.

The final solution of the prechlorine feed problem was a combination of controls. There is a venturi meter on the outlet of the basin. A differential converter was obtained and installed on this venturi tube. The signal from the differential converter is carried to the principal chlorinator so that the feed of chlorine is proportional to the flow of water out of the basin.

This control is quite successful and takes care of the hour-to-hour fluctuations in flow through the filters. It does not solve the problem of the changing chlorine demand in the raw water, however.

This was solved by modifying the prechlorinator by installing a calibrated dial on the control knob. The dial and its calibration were made by the staff on an empirical, observation basis. The dial setting indicates the number of pounds of chlorine per million gallons of water. This arrangement has operated satisfactorily but does involve some judgment on the part of the operator, who must observe the residual recorder and anticipate changes in the quality of the raw water.

To assist in obtaining a more perfect chart, another piece of apparatus has been added. This device is mounted on the chlorine residual recorder and regulates the feed of a second chlorinator to hold a constant residual on top of the filters. This booster chlorinator ensures that the chlorine residual is never less than the desired amount. This instrumentation has been highly successful and has practically eliminated all disturbing variations in the prechlorination feed.

With prechlorination under accurate control, very little difficulty is experienced with postchlorination. A chlorine residual recorder gives a continuous record of the chlorine in the delivered water. If there is any deficiency, it is corrected by the operator utilizing the postchlorination machines. In the overall plant operation, the postchlorination dose will not amount to more than 2–5 per cent of that used in prechlorination. This accurate control of chlorine feeds by instrumentation and automation has eliminated the greatest cause of complaints by customers.

Lime

The feeding of lime has been a matter of much research. Lime is the easiest chemical to control but the most difficult to feed of all those used. As lime is difficult to dissolve and contains a relatively large amount of insoluble material, there is great controversy as to the proper point of application of the lime feed. At one time lime was fed directly into the suction well of the high-lift pumps. Within a year, there was a rash of white-water complaints. Later a dissolving tank was used, which was supposed to remove the insolubles. The effluent of this tank was fed into the suction of the high-lift pumps, but the process was unsatisfactory. It was practically impossible to adjust the lime feed rate to conform to the hour-to-hour variations in pumpage, and consequently the pH of the finished water was never constant. There were also troublesome problems of turbidity caused by feeding the lime into the suction of the high-lift pumps. Because the plant

uses more than 600 tons of lime per year, there must be 10–20 tons of insolubles. Pumping this directly into the system would inevitably lead to difficulties.

The lime could have been added in the clear wells, but this would quickly have produced a deposit that would have required cleaning at great difficulty and expense. Lime has also been fed at the inlet of the coagulation basins, but this does not produce the desired chemical result. A low pH—around 6.5—is needed for the best floc. This floc must be allowed to settle before the pH is raised to the level desired in the finished water. Feeding lime in the effluent from the coagulation basin just before the filters usually results in an objectionable buildup of calcium carbonate on the filter sand. In light of these facts, it would appear that there is no satisfactory place in the flow system of a filter plant for the application of lime.

Lime Feed Experiments

At the Elizabethtown plant, the decision was made to experiment with feeding lime near the outlet end of the coagulation basin. The lime is fed in solution through a 6-in., cast-iron pipe with orifices for uniform distribution. It is introduced about 20 min after prechlorination so that the free residual chlorine will be at the lowest pH possible.

When first tried, the orifices were pointed horizontally, facing the flow of water. This proved unsuccessful as the lime immediately dropped to the bottom of the basin where it gathered in a puddle.

The distribution header was then rotated to direct the orifices upward as shown in Fig. 7. This was successful. The orifices act like jet pumps, creating a substantial rolling movement of the water in this part of the basin. This rotary circulation produced a maximum dissolving of the soluble portions of the lime solutions. As there is about 1 hr detention after the addition of the lime, the insoluble portions settle out on the floor of the basin. This method of lime feeding has been used for more than 2 years, and a careful microscopic and sieve analysis of the filter sand shows no buildup whatever.

Feeding the lime at this point ahead of the filters allows the filters to remove any turbidity resulting from the lime itself. The method has one disadvantage in that if the lime is not controlled accurately and the pH is allowed to rise too high, the floc matte on the filters may be destroyed by the high pH and some turbidity and color may pass through the filters. This failure would be observed quickly in the illuminated clear well.

Feeding the lime solution through the 6-in. header and orifices does pose a problem of keeping the lime clean. About 200 gpm of water at 25 psi is used, to which is added the slurry from the lime feeders. Even with this extremely dilute solution, there is a substantial buildup within the piping. At times it is necessary to run a cleaning tool through the pipe at least once a week to keep it open. The lime solution piping has been laid out carefully to permit this cleaning with a minimum of effort. By means of valves, the cleaning tool can be inserted in a few minutes and the entire cleaning operation completed in less than 15 min. When the water temperature is around 40°F, there is considerable buildup, but with warmer water it is

hardly ever necessary to clean the solution piping.

The control of the lime feed is accomplished by actuating the lime feed machine from the venturi meter at the outlet of the basin. This venturi meter has a transmitter which produces a time-cycle signal. The time signal is carried to the lime feed machine where, through a relay, it starts and stops the feeder in a cycle proportional to the flow. This has been extremely successful, and the pH recorder chart on the outlet of the basin usually appears as a perfect circle. The quantity of lime fed per volume of water is regulated by adjusting the tray setting of the feeder. With the operating time of the feeder proportioned to the flow, a perfect pH chart can be obtained.

Fig. 7. North End of Coagulation Basin

This part of the basin has been partitioned off to form a chlorine contact basin. Chlorine is added through the pipe along the top of the baffle. The 6-in. pipe on the left is used for lime feeding.

Coagulant Aids

The raw waters obtained from the two rivers and the canal pose the continual problem of adjusting the plant chemicals. The most difficult of these is the alum setting to produce the best possible floc. The turbid waters are by far the easiest to treat and pose no problem whatever, as an excellent floc can be obtained at any time. The clearer waters encountered in the drought periods of the summer pose the greatest problem. Without nuclei for the formation of floc, it is most difficult to obtain good coagulation.

Experiments have been made with practically all the accepted coagulant aids. The results obtained have paralleled closely those described by others (*2*).

Although practically all of the various aids make some contributions toward improved floc formation, Elizabethtown experience indicates that activated silica is best. After some research, it was determined that the silica activated with sodium bicarbonate would best meet the requirements of this plant. Further research is under way to determine whether this activation cannot be accomplished with carbon dioxide gas. With a carbonator, such as is used in the ordinary drug store soda fountain, a carbonic acid can be produced with about 1,000 ppm of CO_2 and a pH of 4.3. This carbonic acid appears to be ideal for activation of the silica, and it is believed this method will be reliable and effective. With the activated silica, an excellent floc is obtained even under the most adverse conditions.

Other Chemicals

In addition to the chemicals described above, all of the other standard chemicals used in filter plant practice are employed at this plant.

For algae control, there has been considerable experimentation with copper sulfate without conclusive results. As the raw water is not obtained from a reservoir, the established methods for treating algae in reservoirs with copper sulfate are not applicable. In past years, copper sulfate has been added to the flowing rivers several miles above the intakes. It is believed this treatment was ineffective. At the present time, about 1.0 ppm of copper sulfate is added at the river intakes in order to treat the water in the large basin. No conclusive results have been obtained. There is a difference of opinion as to whether it is wiser to add the copper sulfate and kill the algae in the basin with the possibility of odors from the dead algae, or whether it would be better to allow the algae to stay alive and remove them on the filters.

Ammonia is used in the plant to produce a combined chlorine residual in the finished plant water. No ammonia is used ahead of the clear wells so the chlorine added will be in the form of free residual chlorine and not as the combined chlorine. It is felt that the chlorine-ammonia is desirable in the finished water in order to carry the chlorine residual into the farthest parts of the system.

Soda ash is used for corrosion control the year round. For this purpose it is fed in the finished water. Soda ash is also used to build up the alkalinity so that a good floc can be formed during the winter when the alkalinity of the raw water drops to extremely low levels.

Conclusion

Although the procedures and equipment described may appear to be unnecessarily complicated, they seem to be the only answer to an unusually difficult problem of producing a water that will meet the critical requirements of Elizabethtown's customers.

The instrumentation and automation on the whole are relatively simple and involve a minimum of maintenance. Automation has substantially reduced the man-hour requirements at the plant, which is now producing more than twice as much water with the same manpower that was used 10 years ago. The total cost of chemicals exceeds $150,000 per year. If precise controls can be maintained and minimum dosages used at all times, the savings in chemicals alone will soon pay for the equipment.

Reference

1. Drinking Water Standards, 1946. *Pub. Health Repts.*, **61**:371 (Mar. 15, 1946), *Jour. AWWA*, **38**:361.
2. Cohen, J. M.; Rourke, G. A.; & Woodward, R. L. Natural and Synthetic Polyelectrolytes as Coagulant Aids. *Jour. AWWA*, **50**:4463 (Apr. 1958).

Discussion

Martin E. Flentje

Chief San. Engr., American Water Works Service Co., Inc., Philadelphia, Pa.

Discussing an article such as this is a pleasure. The article is extremely informative, and the author and his associates should be congratulated for a good job well done. The management of the Elizabethtown plant should also be commended for their obvious appreciation of the need for proper facilities to do a good job. Evidences of a progressive, cooperative effort abound in the article: construction changes, sight wells, recording flow colorimeter, periscopes, hot-water fountains, chlorine residual recorders, automatic residual-controlled chlorinators, proportional-feed chlorinators, dry feeders, and pH recorders—to mention a few.

The article illustrates some interesting facts:

1. A high-quality water that meets today's exacting consumer demands can be produced from difficult raw-water sources, even in older purification plants, if the problem is approached with intelligence and a willingness, when necessary, to depart from conventional methods.

2. A high degree of automation and instrumentation is available to the water treatment supervisor. The results at the Elizabethtown plant demonstrate how useful these instruments can be in eliminating human errors and in improving control of treatment. They also demonstrate that this type of instrumentation pays dividends.

3. There is still a lack of fundamental knowledge in certain chemical treatments; it is not known how to measure the point or condition at which a water is actually coagulated, prevent deposition in lime lines, or prevent turbidity increases when a supposedly highly soluble, hydrated lime is added to the clear well.

Effectiveness of Polyelectrolyte Coagulant Aids in Turbidity Removal

A. P. Black, A. I. Ball, A. L. Black, R. A. Boudet, and T. N. Campbell

A contribution to the Journal by A. P. Black, Research Prof., A. I. Ball, Research Asst., A. L. Black, Research Asst., R. A. Boudet, Research Asst., and T. N. Campbell, Research Asst.; all of the Dept. of Chemistry, Univ. of Florida, Gainesville, Fla. *This investigation was supported by Research Grant RG-4516 from the National Institutes of Health, USPHS, Washington, D.C.*

VERY recently Cohen (*1*) reported the results of his studies of three polyelectrolytes, two of which were synthetic organic compounds, one anionic and the other cationic. The third was a naturally derived material admixed with clay. He found all of them to be effective in varying degree as coagulant aids but pointed out that, because no natural waters are entirely alike and polyelectrolytes, natural and synthetic, vary widely in nature and composition, it is difficult to generalize on the behavior of these materials. The paper includes a survey of the literature in this new and interesting field and presents valuable data on the three materials studied.

The action of some of these materials verges on the spectacular. Others are ineffective and in certain situations actually inhibit coagulation and retard settling. Because of these differences in behavior it has been felt that further study of a substantial number of these materials might prove worth while, not only by providing comparative data but—more important—by throwing additional light on the basic mechanisms of coagulation. Accordingly, this article presents the results of a study of seventeen polyelectrolytes, including most of those which have been approved to date as nontoxic by the USPHS Advisory Committee on Coagulant Aids in Water Treatment (*2*). These studies have been confined to the effectiveness of the materials as coagulant aids in the removal of turbidity with alum. A later article to appear in the JOURNAL will present the results of work now in progress on their effectiveness when used with alum and ferric sulfate in the removal of organic color and also when used in lime or lime-soda softening. It is also planned to include some preliminary electrophoretic data on the effect of these materials on zeta potentials.

Table 1 lists the trade names and manufacturers of seventeen materials selected for study and alphabetically identifies them. Although the chemical composition of most of the materials was not supplied by the manufacturers, five were probably polymeric amides, quite possibly similar to polyacrylamide; one was a polycationic polymer in an approximately 1*N* sodium hydroxide solution; one was a carbohydrate material derived from seaweed; one was a specially processed starch; one

was a byproduct of wood pulp, composed of ammonium lignosulfonates; two were derived from guar gum; one was carboxymethyl cellulose; one was a protein material; and several contained clay. The list includes the three studied by Cohen and they are similarly identified.

Experimental Procedure

The preparation of a stable clay suspension of colloidal dimensions, from which suspensions of known turbidity could be prepared in demineralized water, was first undertaken. For this purpose use was made of several standard clays originally collected and characterized by the American Petroleum Institute (API) in Research Project 49. These clays are no longer available from API but 29 of them have been collected from the same original sources and are believed to be identical with those characterized by API. A number of these clays were obtained for this work and attempts made to prepare stable suspensions. Those finally chosen were a kaolinite (K-4) and an illite (I-35). The illite was chosen because it yielded a fine, slow-settling floc upon the addition of alum. This was encouraging because one of the advantages claimed for these coagulant aids is increase in floc size. Stock suspensions of the two clays were prepared by suspending 50-g samples of each in demineralized water with a food blender. In order to improve stability, 25 ml of 0.1*M* $Na_4P_2O_7$ was added to the I-35 and a lesser volume, 10 ml, to the more stable K-4. The concentration of $P_2O_7^{-4}$ ion in the diluted suspensions used for this group of jar tests did not exceed 2 mg/l. Even with this method, suspensions were not completely stable, nor

TABLE 1

Identification of Seventeen Coagulant Aids Studied

Designation of Coagulant Aid	Trade Name	Form	Manufacturer
Anionic A*	Separan 2610	White powder	Dow Chemical Company
Cationic B*	Nalco 600	Yellow liquid	National Aluminate Corporation
Nonionic C*	Jaguar MDC	Gray powder	Stein, Hall & Company
D	Reagent X-309	White powder	American Cynamid Company
E	Keltex	White powder	Kelco Company
F	Reagent S-3019	White powder	American Cynamid Company
G	Orzan P	Brown powder	Crown Zellerbach Corporation
H	Reagent 182	White powder	American Cynamid Company
I	Reagent S-3100	White powder	American Cynamid Company
J	N Brand Silica	Clear liquid	Philadelphia Quartz Company
K	Drewfloc	Gray liquid	E. F. Drew & Company
L	Permutit 65	White powder	The Permutit Company
M	Claron	White liquid	Allyn Chemical Company
N	Cellulose Gum	White powder	Hercules Powder Company
O	Arquad 2HT	Brown liquid	Armour & Company
P	Nalco 2	Yellow liquid	National Aluminate Corporation
Q	Nalco D-1444	Black liquid	National Aluminate Corporation

* Also studied by Cohen (*1*).

were alum dosages reproducible. This should be recalled in interpreting the experimental results.

The original turbidity was measured with a Jackson candle turbidimeter, although after the strength of the original standard suspension had been adjusted by this method a photometer * was used for measuring turbidities. This instrument employs a 15-cm light path. A 650-mμ filter was used. The standard clay suspensions were prepared in 55-gal batches and kept in suspension in a polyethylene drum equipped with a stirrer.

Before beginning the tests it was thought desirable to attempt to evaluate the variables involved in the jar test. The five variables checked were: [1] the rate of addition of alum solution—that is, very rapidly or by drops; [2] the rate of stirring; [3] the size of samples and shape of jars; [4] the length of stirring time; and [5] the age and concentration of the alum solutions.

None of the variables investigated made a significant difference in the final turbidity obtained for a given dosage. Therefore, the method adopted in running jar tests for turbidity removal was as follows:

One-liter samples of demineralized water containing 100 mg/l turbidity were placed in square jars of 1,500-ml capacity. The previously determined minimum dosage of alum necessary to produce a floc was first added, followed by increased dosages of the coagulant aid being studied. The coagulant aid was added a minute after the alum solution. This was standard procedure. It is possible that in some cases better results might have been obtained had the order of addition been reversed. All tests were run at a temperature of 24–26°C. No rapid mixing was employed, all jars being stirred for 30 min at 40 rpm.

The method used for simultaneously withdrawing six samples by suction, one from each jar, at 1-, 5-, and 30-min intervals, was that devised by Cohen (*3*). The criteria used in evaluating the action of the various coagulant aids were the character and rate of settling of the flocs and the turbidity of the settled waters.

TABLE 2

Effectiveness of Varying Dosages of Alum and Cationic B on Turbidity Removal

Alum *mg/l*	Cationic B *mg/l*	Turbidity—*mg/l*		
		1 min	5 min	30 min
6.0	0.0	19.1	18.4	16.8
6.0	5.0	5.0	5.3	4.5
3.0	0.0	100.0	98.0	96.0
3.0	5.0	4.0	3.4	3.4
2.0	0.0	88.0	88.0	88.0
2.0	6.0	3.0	3.0	3.0
1.0	0.0	98.0	96.0	96.0
1.0	12.0	4.5	2.2	3.4

Discussion of Results

For each clay suspension the minimum alum dosage required for marginal flocculation was established. Marginal flocculation is defined as the first appearance of floc, and not that obtained for maximum settling and turbidity removal. With this minimum alum dosage for each jar test conducted, varying amounts of several coagulant aids were added. It must be realized that the minimum alum and coagulant aid dosages varied slightly with the age of the stock clay suspensions. For each coagulant aid tested,

* Lumetron, Model 450; a product of the Photovolt Corporation, New York.

a graph is presented on which the settling rate is plotted against the final turbidity.* Each graph also carries a note giving the dosages of alum and coagulant aid employed in the test. The following discussion of the coagulant aids tested outlines the range of dosages employed and their effects on the settling rate and final turbidity of the clay suspensions.

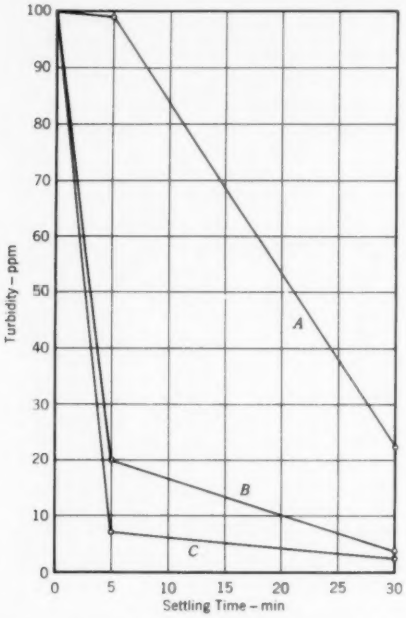


Fig. 1. Effect of Anionic A on Settling of Alum Floc With 100 mg/l I-35 Clay

Curves A, B, *and* C *represent runs made with 0, 4, and 5 mg/l Anionic A, respectively; alum concentrations in all three tests were 10 mg/l.*

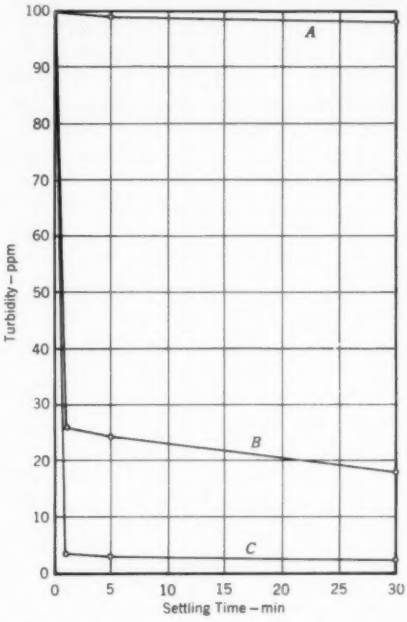


Fig. 2. Effect of Anionic A on Settling of Alum Floc With 100 mg/l K-4 Clay

Curves A, B, *and* C *represent runs made with 0, 2.5, and 6.25 mg/l Anionic A, respectively; alum concentrations were 12.5 mg/l in each test.*

Anionic A was extensively studied on both clays to provide a basis for comparison with results obtained by Cohen (*1*) on naturally turbid waters and to compare the effects of various alum dosages on the amount of Anionic A needed for maximum turbidity removal. Increase in dosage from 0.5 to 7.5 mg/l Anionic A increased the settling rate and floc size and decreased final turbidity when dosages of 7.0–20.0 mg/l of alum were added to produce marginal flocculation. At a given alum dosage, increased amounts of Anionic A consistently gave increased settling rates and turbidity removal. Figures 1 and 2 are typical of these results.

* Throughout the illustrations, final turbidities are expressed in parts per million, this being the unit most commonly used in plant practice.

Cationic B acted as a true coagulant when used with the K-4 clay suspension. A dosage of 60.0 mg/l was required to reduce the K-4 clay suspension to a turbidity of less than 10 mg/l, however. Figure 3 indicates that increased dosages of Cationic B did little varying dosages of this coagulant aid and alum were used in jar tests. The dosage of alum was varied between 1.0 and 6.0 mg/l, whereas that of Cationic B was varied between 0.25 and 13.0 mg/l. Some of the results are presented in Table 2.

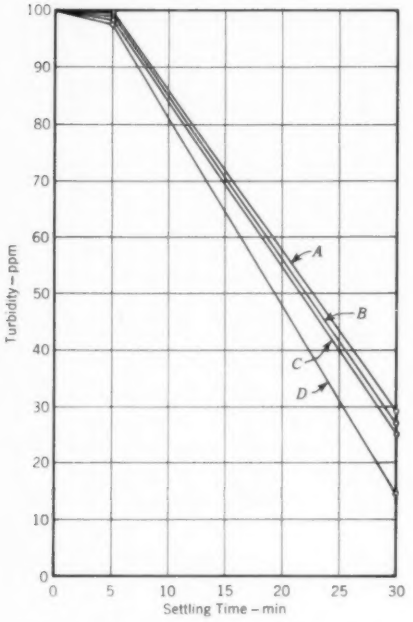


Fig. 3. Effect of Cationic B on Settling of Alum Floc With 100 mg/l I-35 Clay

Curves A, B, C, *and* D *represent tests made with 3, 6, 0, and 4 mg/l Cationic B, respectively; alum concentrations were 11 mg/l in each test.*

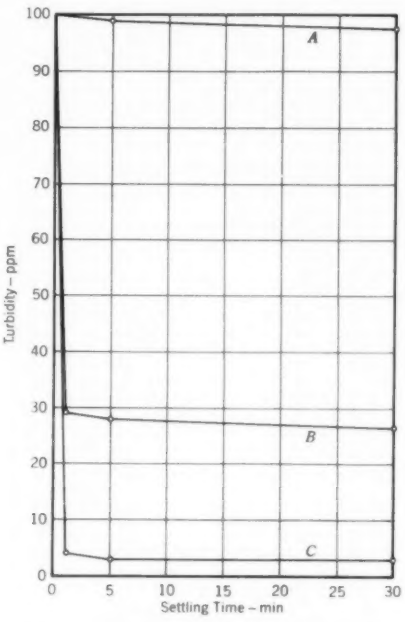


Fig. 4. Effect of Cationic B on Settling of Alum Floc With 100 mg/l K-4 Clay

Curves A, B, *and* C *represent runs made with 0, 3, and 6 mg/l Cationic B, respectively; alum concentrations were 3 mg/l in each test.*

to improve either the settling rate or final turbidity. The data indicate that an optimum dosage of 4.0 mg/l Cationic B must be used with alum for maximum settling rate and turbidity removal. Because it had been found that Cationic B was a true coagulant,

With I-35, Cationic B was not found to be a true coagulant in dosages up to 70.0 mg/l. Therefore, 9.0–18.0 mg/l alum was added to cause marginal flocculation. The coagulant aid was used in dosages between 1.0 and 7.0 mg/l. Although improved settling

rates and final turbidities were observed with low dosages, the effects were not as marked as with K-4. At higher dosages, Cationic B inhibited rather than increased the settling rate and removal of final turbidity. This is shown in Fig. 4.

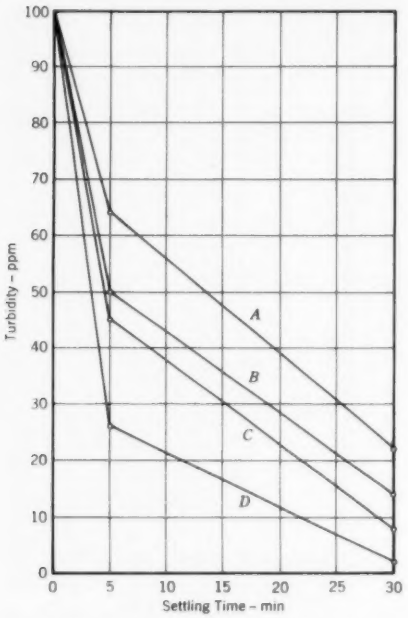


Fig. 5. Effect of Coagulant Aid C on Settling of Alum Floc With 100 mg/l I-35 Clay

Curves A, B, C, *and* D *represent runs made with 10, 0, 1, and 2 mg/l Coagulant Aid C, respectively; alum concentrations were 10 mg/l in each test.*

Coagulant Aid C was tested on clay I-35 in dosages of 1.0–10.0 mg/l. The addition of 1.0–4.0 mg/l Coagulant Aid C improved the settling rate and final turbidity removal with a minimum amount of alum. However, in dosages from 5.0 to 10.0 mg/l Coagulant Aid C inhibited floc formation. Figure 5 indicates the results obtained.

Coagulant Aid D was tested on clay K-4 in dosages of 0.25–3.0 mg/l. With dosages of 0.25–1.0 mg/l this coagulant aid improved the settling rate and final turbidity, the optimum

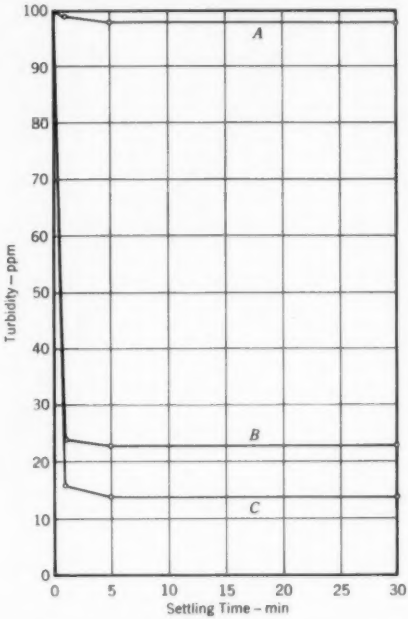


Fig. 6. Effect of Coagulant Aid D on Settling of Alum Floc With 100 mg/l K-4 Clay

Curves A, B, *and* C *represent runs made with 2, 0, and 0.25 mg/l Coagulant Aid D, respectively; alum concentrations in each test were 3 mg/l.*

dosage being 0.5 mg/l. With dosages of 1.0–3.0 mg/l, Coagulant Aid D produced progressively more floc inhibition. Figure 6 shows the optimum results obtained with this aid. Coagulant Aid B was also tested on clay I-35 in dosages of 0.25–3.0 mg/l. A nar-

rower range of optimum dosage was obtained—that is, 0.25–0.50 mg/l. Dosages of 0.75–3.0 mg/l yielded successively decreasing settling rates and higher turbidities, as shown in Fig. 7.

Coagulant Aid E was used with both K-4 and I-35 clays. With the K-4 suspension, Coagulant Aid E did not aid coagulation in concentrations of 0.5–10.0 mg/l. In fact, inhibition of coagulation was increased in proportion to the amount of the aid that was added. This is clearly shown in Fig. 8.

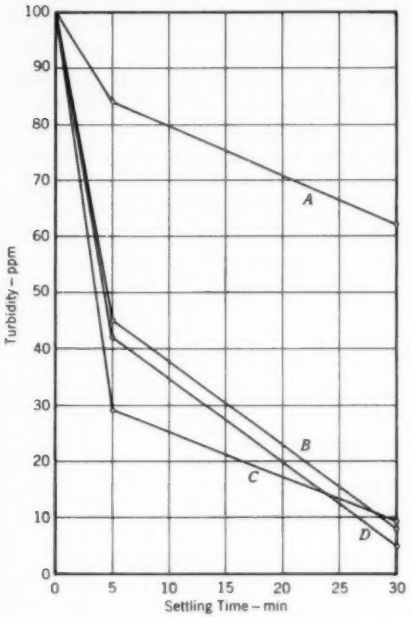


Fig. 7. Effect of Coagulant Aid D on Settling of Alum Floc With 100 mg/l I-35 Clay

Curves A, B, C, *and* D *represent runs made with 3.0, 0.0, 0.25, and 0.75 mg/l Coagulant Aid D, respectively; alum concentrations were 8.0 mg/l for each test.*

With clay suspensions of I-35, increased dosages of 0.5–5.0 mg/l of the coagulant aid gradually improved the settleability and final turbidity of the samples. Figure 9 gives these results.

Coagulant Aid F was tested on I-35 in dosages of 0.2–10.0 mg/l. The addition of 0.2–1.0 mg/l slightly aided coagulation. When 1.0–10.0 mg/l was added, it acted as a dispersant. This dispersing action increased with increased dosage. Figure 10 represents these results.

Coagulant Aid G, in dosages of 0.1–10.0 mg/l, was not effective in coagu-

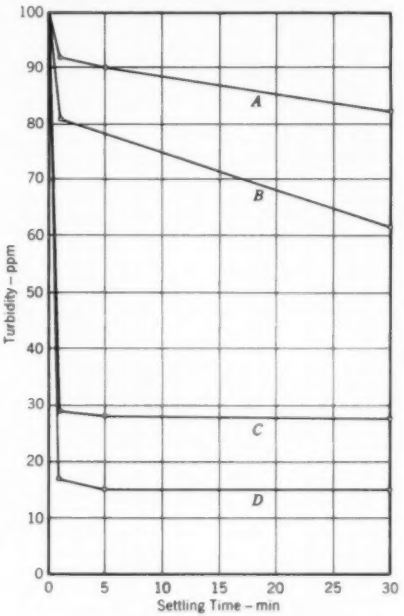


Fig. 8. Effect of Coagulant Aid E on Settling of Alum Floc With 100 mg/l K-4 Clay

Curves A, B, C, *and* D *represent runs made with 10, 1, 0.5, and 0.0 mg/l Coagulant Aid E, respectively; alum concentrations were 3 mg/l for each test.*

lating I-35. Figure 11 is typical of the results of such tests and indicates that increased dosages decrease settleability and final turbidity.

Tests on Sodium-Saturated I-35

Cohen, in his experiments with three polyelectrolytes (*1*), found that

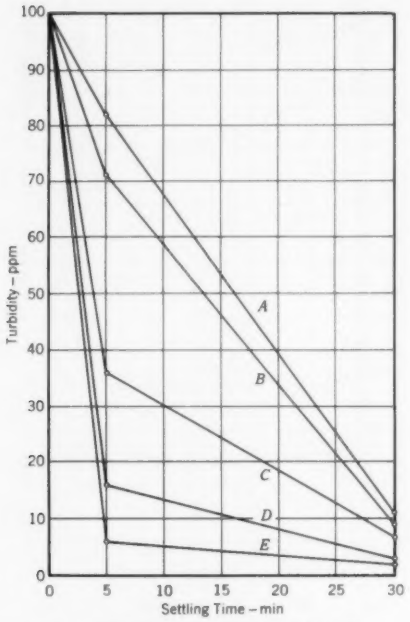


Fig. 9. Effect of Coagulant Aid E on Settling of Alum Floc With 100 mg/l I-35 Clay

Curves A, B, C, D, *and* E *represent runs made with 0.0, 0.5, 1.0, 2.0, and 3.0 mg/l Coagulant, Aid E, respectively; alum concentrations were 10 mg/l for each test.*

one of them was not effective in a soft, prepared laboratory water but was quite effective in five natural waters and in prepared water containing calcium hardness. The foregoing experiments were carried out with clays suspended in deionized water to which a small amount of sodium pyrophosphate was added to improve the stability of the suspensions. The data, however, although useful in comparing the behavior of various coagulant aids under these conditions of use, do not necessarily indicate what the result would be if they were used with waters containing hardness and dissolved salts. It was therefore decided to repeat the work with these and other coagulant aids under conditions more nearly like those in the average water plant. Accordingly, a water was prepared from calcium chloride and sodium bicarbonate having the composition given below:

Item	Concentration *ppm*
Calcium ion (Ca)	25
Sodium ion (Na)	19
Bicarbonate ion (HCO_3)	50
Chloride ion (Cl)	44
Carbonate hardness ($CaCO_3$)	41
Noncarbonate hardness ($CaCO_3$)	22
Total hardness ($CaCO_3$)	63

Synthetic turbid water was prepared in 50-gal batches by suspending sodium-saturated clay I-35 in this water.

Special emphasis was given to the preparation of the I-35 before its subsequent suspension in the mineralized water. The clay was first ground to a fine powder, placed in a saturated NaCl solution, and permitted to saturate thoroughly by mixing at a high speed in a blender for 2 hr, which greatly increased the exchange of sodium ions for the clay cations. The suspension was then dialyzed to peptize the clay until a specific conductance of 60 micromhos per centimeter was obtained. This suspension was then centrifuged at about 1,500 rpm

for 15 min to remove all large particles, which insured a suspension of more uniform particle size, and was added to the synthetic water. The sodium saturation procedure provides a more stable clay suspension and eliminates the highly-negative, colloid-stabilizing $P_2O_7^{-4}$ anion.

Three of the coagulant aids, representative of the anionic, cationic, and nonionic groups, were first used on the synthetic water. Six additional aids were used to determine their effects on turbidity removal. In each case the minimum alum dosage required to produce marginal flocculation was established. In spite of careful preparation of the clay suspension, aging of the suspension caused variations in the alum dosage. The clay suspension was prepared and stored in a 55-gal polyethylene container equipped with a stirrer.

The amount of turbidity was initially evaluated nephelometrically by a special nephelometer attachment on the photometer. Although this light-scattering recorder provided a sensitive index for measuring relative numbers of suspended particles in the water, no reliable primary colloidal standard was available for accurate standardization of the instrument. Samples read on and reported from the nephelometer attachment indicate only comparative data. Therefore, a reproducible method for evaluating low turbidities in water against a primary standard was adopted by using a spectrophotometer * equipped

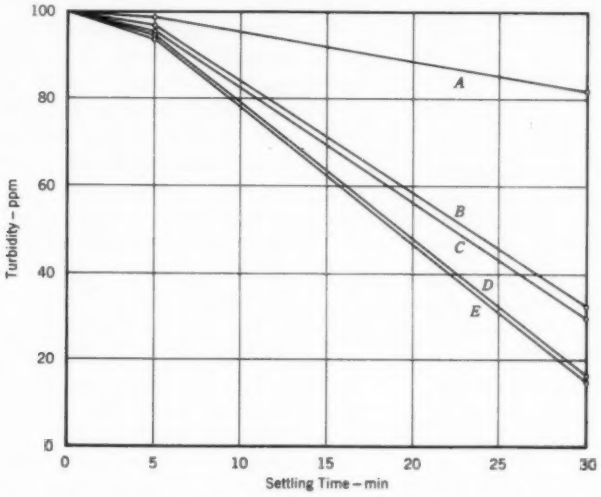


Fig. 10. Effect of Coagulant Aid F on Settling of Alum Floc With 100 mg/l I-35 Clay

Curves A, B, C, D, *and* E *represent runs made with 0, 1, 3, 5, and 10 mg/l Coagulant Aid F, respectively; alum concentrations were 9 mg/l in each test.*

* Model DU; a product of Beckman Instruments, Inc., Fullerton, Calif.

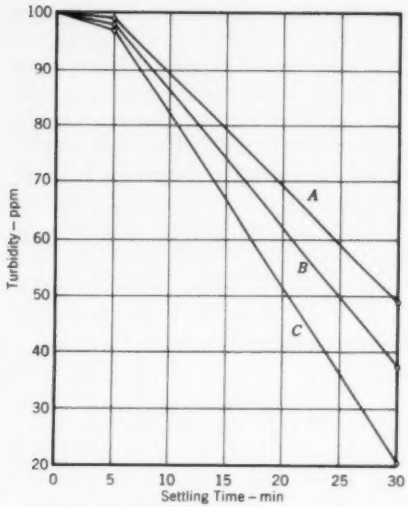


Fig. 11. Effect of Coagulant Aid G on Settling of Alum Floc With 100 mg/l I-35 Clay

Curves A, B, *and* C *represent runs made with 3, 4, and 0.0 mg/l Coagulant Aid G, respectively; alum concentrations were 8 mg/l in each test.*

with a 10-cm cell. Turbidities were measured at 420 mμ, a wavelength of maximum light scattering, and results are expressed in parts per million.

The experimental procedure followed in these experiments was similar to that used in the first series except that turbidities were read at 10- and 30-min intervals.

Discussion of Results

The following discussion is limited to the effects of varying increments in the coagulant aid dosages used in conjunction with a minimum dosage of alum to produce marginal flocculation. In the graphs, dosages of coagulant aid are plotted against turbidity. Curves are shown for both 10-min and 30-min settling times.

Anionic A dosages in the range 0.25–3.0 mg/l were employed and the results obtained were similar to those obtained by Cohen. It was most effective in increasing floc size and reducing turbidity in dosages of less than 0.5 mg/l. In this range floc formation was spectacular and the floc could be described as immense. In the dosage range 0.5–3.0 mg/l, floc particles were fewer in number, but those that did form were fairly large, similar to those formed in the previous work with demineralized water, and settled well. As shown in Fig. 12, however, after a 30-min settling turbidities increased with increasing dosages up to the highest used, 3.0 mg/l.

Cationic B dosages of 0.25–3.0 mg/l were used, and in this dosage range results were similar to those obtained by Cohen. With dosages of less than 1 mg/l, floc formation was improved, settling was good, and final turbidities lowered. In dosages from 1.0–3.0 mg/l, however, floc formation and settling were not so good, and both 10- and 30-min turbidities, although lower than the alum controls, were higher

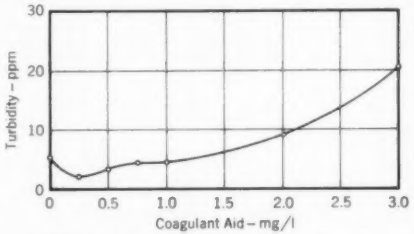


Fig. 12. Effect of Anionic A on Final Turbidity

The curve shows the effect of various concentrations of the coagulant aid in solutions with 4 mg/l alum after 30-min settling.

than those obtained with dosages of less than 1.0 mg/l. In the tests with clay suspensions in demineralized water, this coagulant aid was found capable of producing flocculation alone. This test was not made with the synthetic water, but there is no reason to believe that its action would differ. The data are shown graphically in Fig. 13.

Nonionic C, according to preliminary tests, was extremely effective in small dosages, and its action was therefore studied in the dosage range 0.02–1.0 mg/l. Over this entire range, final 30-min turbidities were almost identical, not only indicating the effectiveness of this aid in extremely low concentrations, but also that increasing amounts show no inhibiting action. Even more surprising, turbidities after a 10-min settling were almost as low as after 30 min, and at a dosage of 0.2 mg/l, minimum turbidity was obtained in a 10-min settling period. Flocs were large and well formed and settled rapidly. The data are shown in Fig. 14.

Coagulant Aid E was tested in dosages 0.2–2.5 mg/l. Increased 10-min settling was observed in this range for alum alone, 0.2 mg/l being the optimum dosage. The floc here was very large, settling was rapid, and clarification was good. With 30-min settling, dosages of 1.5–2.5 mg/l gave higher final turbidities than the alum control. These results are shown in Fig. 15 and 16.

Coagulant Aid G was tested in dosages of 0.2–2.5 mg/l. Within this entire range floc formation was inhibited, settling was poor, and turbidities higher than with the alum control. This is shown graphically in Fig. 17.

Coagulant Aid J was tested over an unusually broad range of dosages, from 1.0 to 10.0 mg/l. Its behavior with I-35, a clay that is difficult to coagulate, was not impressive. In low dosages floc formation was good, but settling was only fair. Higher dosages peptized the floc. In all dosages tested, 30-min turbidities were higher than with the alum control. A few tests were made by adding the aid after the alum floc was well formed. In these tests the floc particles were strengthened and settling was improved, but 30-min turbidities remained higher than the control. The results are shown graphically in Fig. 18.

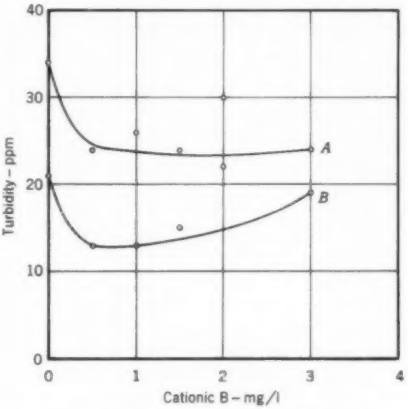


Fig. 13. Effect of Cationic B on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling, respectively; alum concentrations were in both tests 8 mg/l.*

Coagulant Aid K was tested in dosages of 0.2–4.0 mg/l. Its behavior was somewhat unusual. In the low dosage range of 0.2–1.0 mg/l, floc formation was inhibited and 30-min turbidities were higher than in the control. In the intermediate dosage range of

1.0–3.5 mg/l, 30-min turbidities were lower than in the control, but when the dosage was increased to 4.0 mg/l final turbidity sharply increased. This is shown graphically in Fig. 19.

Coagulant Aid L was tested in the fairly wide dosage range of 0.2–6.0 mg/l, and most pronounced results were obtained in the low dosage range. Figure 20 shows that the curve of 10-min turbidities dropped sharply in the dosage range of 0.2–2.0 mg/l, whereas the 30-min turbidity curve is practically flat in this dosage range. With dosages of 2.0–6.0 mg/l final turbidities for 10- and 30-min settling periods were identical. In other words, the outstanding characteristic of this aid is that in all dosage ranges tested it produced a floc which settled rapidly.

Coagulant Aid M was tested in dosages of 0.2–4.0 mg/l. In dosages of up to 2.0 mg/l this aid produced flocs which settled poorly. Ten-minute turbidities were substantially higher than in the control. With dosages of 2.0–4.0 mg/l settling was more rapid. The 30-min settling curve was practically flat. Throughout the entire dosage range, final turbidities were slightly lower than in the alum control. This is shown in Fig. 21.

Coagulant Aid N was tested in dosages of 0.2–4.0 mg/l and its behavior was quite unusual. It was most effective in aiding floc formation, setting, and turbidity removal at a dosage of only 0.2 mg/l. In the dosage range of 0.2–1.5 mg/l, floc formation was inhibited and 30-min turbidities were higher than in the control, the difference increasing with increasing dosages of the aid. The curves of Fig. 22 indicate that a point of maximum inhibition of coagulation was reached at a dosage of 1.5 mg/l, beyond which there was some improvement; however, 30-min turbidities in the range were substantially higher than in the control.

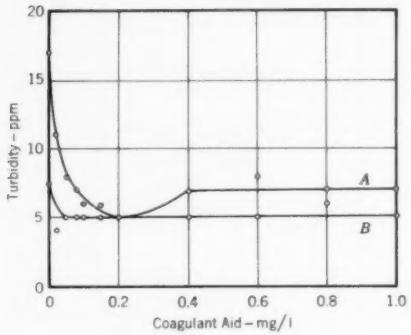


Fig. 14. Effect of Nonionic C on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling, respectively; alum concentrations were 7 mg/l for both tests.*

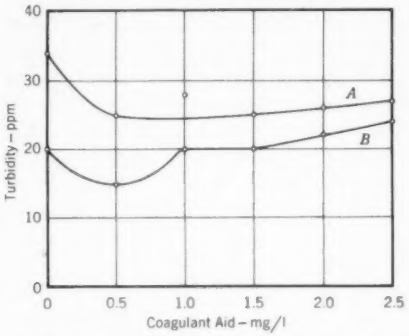


Fig. 15. Effect of Coagulant Aid E on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling, respectively; alum concentrations were 7 mg/l for both tests.*

Coagulant Aid O was tested in the dosage range of 0.5–2.5 mg/l and, as indicated by the two curves of Fig. 23, it had little or no effect on floc formation, settling, or final turbidity. The material was viscous and sticky. Flocs were small and settling was poor.

Coagulant Aid P was tested in dosages of 0.2–4.0 mg/l and its behavior was similar to Coagulant Aid N. Like the latter, it aided floc formation and produced a better settling floc this range it was not particularly effective. The flocs formed were small and settled poorly, but up to a dosage of approximately 1.5 mg/l turbidities were somewhat lower than in the control. At a dosage of more than 1.5 mg/l, however, turbidities increased and at the higher dosages they were greater than they were in the control. Figure 25 is a graphical presentation of data for tests with Coagulant Aid Q.

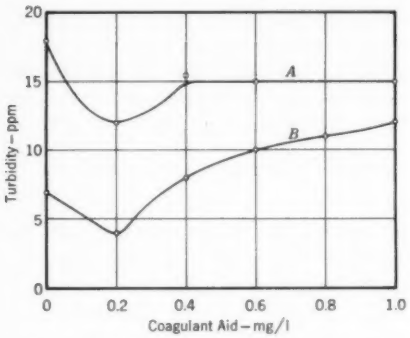


Fig. 16. Effect of Coagulant Aid E on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling, respectively; alum concentrations were 7 mg/l for both tests.*

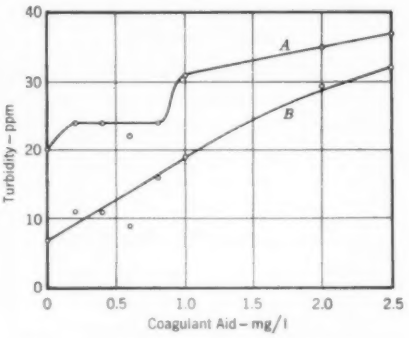


Fig. 17. Effect of Coagulant Aid G on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling, respectively; alum concentrations were 7 mg/l in both tests.*

and lower final turbidity in dosages of less than 1 mg/l. The 10-min settling curve of Fig. 24 shows that, as with Coagulant Aid N, a point of maximum inhibition of floc formation was reached at an intermediate dosage, in this case 2.0 mg/l, after which improved performance was noted. This area of floc inhibition is not so noticeable in the 30-min settling curve, but was definitely present.

Coagulant Aid Q was tested in the dosage range of 0.2–4.0 mg/l and in

Discussion

The seventeen materials studied varied widely in nature and in composition. Some of them consisted entirely of polyelectrolyte which, in some cases, was naturally derived and in other cases synthetic. Others appeared to be mixtures of polyelectrolyte and inorganic material, some of which appeared to be inert and insoluble. What this means in practice is that a method of solution or suspension that will be

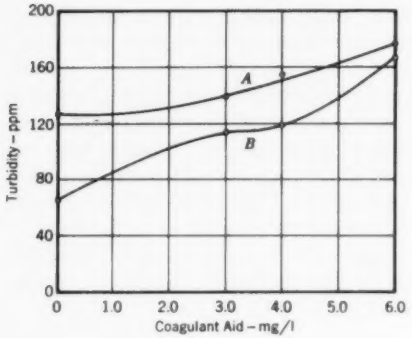


Fig. 18. Effect of Coagulant Aid J on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling, respectively; alum concentrations were 7 mg/l in both tests.*

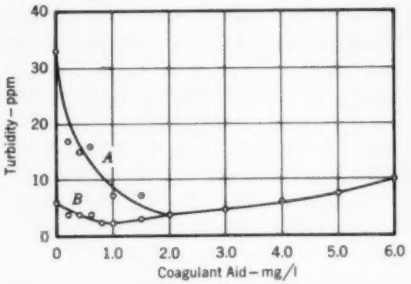


Fig. 20. Effect of Coagulant Aid L on Final Turbidity

After addition of 2.0 mg/l Coagulant Aid L final turbidities were practically identical for both 10- and 30-min settling, and remained at nearly the same level with the addition of larger amounts of the aid. Curves A *and* B *represent 10- and 30-min settling, respectively.*

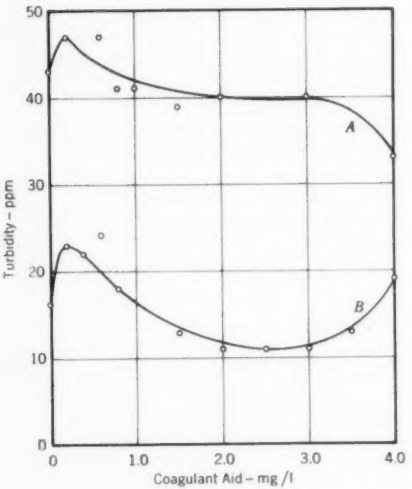


Fig. 19. Effect of Coagulant Aid K on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling, respectively; alum concentrations were 7 mg/l in both tests.*

successful for one material will not work with another. Unless extremely high mixing velocities are employed, some of the natural polyelectrolytes have a tendency to form gummy balls which cannot be dispersed by further agitation. Such materials are not available as coagulant aids. Furthermore, solutions of some of these materials develop high viscosities at low concentrations so that unusually large volumes of water must be used to suspend them. Most of them appear to exert maximum activity if the period of hydration is prolonged with good stirring. Deterioration of aged suspensions of the natural polyelectrolytes was observed in the absence of a preservative, but this would not present a problem in usual plant practice.

No attempt has been made in these studies to evaluate the materials on a cost basis, although the authors have tried to limit the dosages used to those which would be economical in actual

practice, keeping in mind, as was pointed out by Cohen, that benefits to be derived from the use of some of these materials may well override considerations of cost.

The USPHS has established the Technical Advisory Committee on Coagulant Aids for Water Treatment, whose primary function is to review all aspects of toxicity concerning the use of these materials in municipal water supplies. This study has, however, not been limited to investigation of the relatively few nontoxic aids which have been approved to date by that committee (*2*), because toxicity would not ordinarily constitute a problem in the treatment of industrial waters.

Conclusions

This article presents the results of studies of the effectiveness of seventeen coagulant aids in the removal of clay turbidity by coagulation with alum. In the first part of the work two different clays—one easy and one difficult to coagulate—were suspended in demineralized water. In the second part of the work the clay that was difficult to coagulate was sodium saturated and suspended in a synthetic water of moderate mineral content. The following conclusions may be drawn from the data presented.

1. These materials vary widely in their effect on floc formation. At least one of them, used in conjunction with alum, forms immense floc particles. Several produced flocs which were large and well formed; others produced flocs which were small and dense; a few gave floc particles which were very fine and poorly formed; and at least two of them inhibited or entirely prevented floc formation.

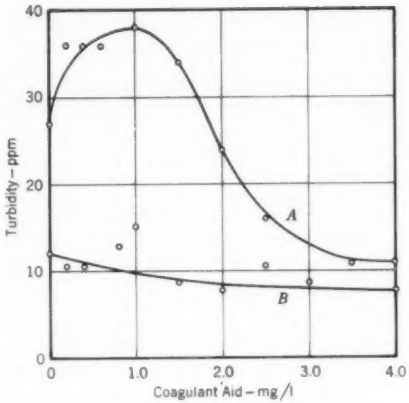


Fig. 21. Effect of Coagulant Aid M on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling, respectively; alum dosages were 3 mg/l in both tests.*

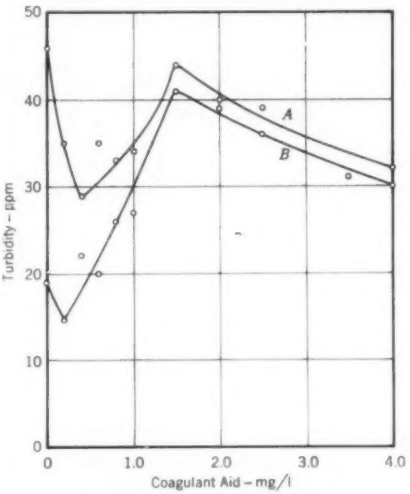
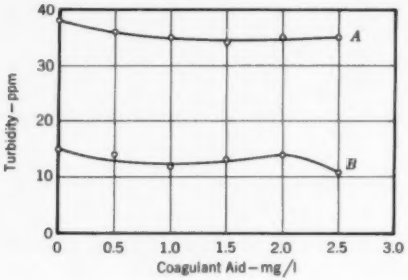


Fig. 22. Effect of Coagulant Aid N on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling respectively; alum dosages were 3 mg/l in both tests.*

Fig. 23. Effect of Coagulant Aid O on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling respectively; alum dosages were 7 mg/l in both tests.*



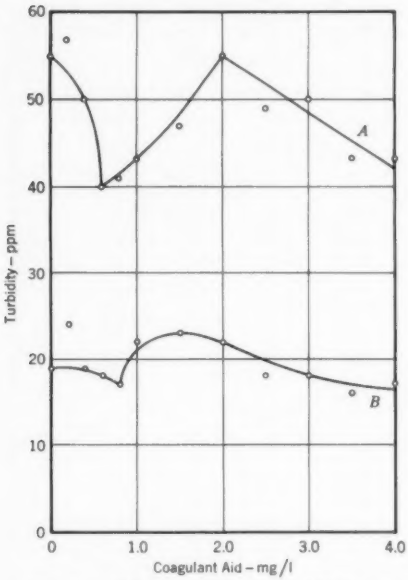


Fig. 24. Effect of Coagulant Aid P on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling respectively; alum dosages were 7 mg/l in both tests.*

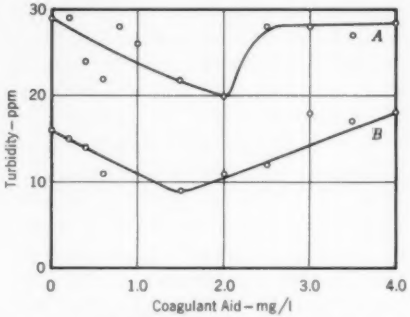


Fig. 25. Effect of Coagulant Aid Q on Final Turbidity

Curves A *and* B *represent runs made with 10- and 30-min settling respectively; alum dosages were 8 mg/l in both tests.*

2. The type of settling observed varied from very poor to excellent with many intermediate gradations. In general, large, well formed flocs settled well and turbidity reduction was good. There were tests, however, in which large flocs settled poorly and small, dense flocs settled fairly well.

3. Most of the materials tested were effective to a greater or lesser degree in reducing the turbidity of the settled water to values below the corresponding controls. Some of them, however, had little effect, and a few so inhibited flocculation that final turbidities were much higher than in the controls.

4. Most of the materials tested were effective in low concentrations—many of them in fractions of 1 mg/l. Increased dosages in some tests showed increased benefits, in others little or no benefit, and in still others actual inhibition of coagulation.

5. The order of addition of the coagulant and the aid was found to be important; in most of this work the aid was added a minute after addition

of the alum. When the effectiveness of a coagulant aid on a given water is being studied, this point should always be checked, because some of them may assist in floc formation and others may merely strengthen or increase the size of floc after it has been formed.

These conclusions are essentially the same as those reached by Cohen in his recent study of the effectiveness of three of these materials on turbidity removal by alum coagulation. Their effectiveness in very small dosages, and the rather spectacular results obtained in some tests by his and the present research, would imply that coagulant aids would probably be effective also in color removal with alum or ferric sulfate and in the coagulation and settling of the sludge produced in lime–soda softening. Accordingly, a study is underway of the action of 23 of these materials on those treatment processes. Results obtained to date indicate that some of them are much more effective in color removal or lime–soda softening than in turbidity removal, although with others the reverse is true. Several of them may be used as the only coagulant for lime–soda-softening sludges, and in dosages far smaller than those necessary for the coagulants customarily employed. Electrophoretic studies are also being made in an attempt to explain the differences in results obtained with these materials. The data obtained should add to the understanding of the basic mechanisms of coagulation.

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2. Coagulant Aids for Potable-Water Treatment. *Jour. AWWA*, **51**:233 (Feb. 1959).
3. Cohen, Jesse M. Improved Jar Test Procedure. *Jour. AWWA*, **49**:1427 (Nov. 1957).

Water Problems in Freezing Weather

Ernest D. Hawkins

A paper presented on Sep. 23, 1958, at the Kentucky-Tennessee Section Meeting, Memphis, Tenn., by Ernest D. Hawkins, Supt., Water Bureau, Knoxville Utilities Board, Knoxville, Tenn.

THE purpose of this article is to present a brief, descriptive treatment of the experiences, methods, and operating procedures of the Knoxville, Tenn., water system during freezing weather in its attempt to maintain the continuity of water service under adverse circumstances. An analytical treatment of frost penetration, density, texture, and thermal conductivity of soils, and other phenomena such as supercooling of water and formation of frazil ice and solid ice crystals is beyond the intended scope of this discussion.

Climate

The states of Kentucky and Tennessee, being located within the region of the southeastern United States, normally have a mild, temperate climate. Spring weather comes early in the year, summer is quite long, and the fall season usually brings only a few mild freezes. Winters in this region are usually quite mild compared to those of Canada or the northern United States. The freezing weather which causes the greatest concern is usually encountered during January and February. A mild freeze, usually at night, followed immediately by warmer weather is the usual pattern.

Subzero or near-zero temperatures are encountered only occasionally and are then usually of less than 24-hr duration. Although subzero weather conditions that last for several consecutive days are rare, February 1958 brought just such a period of sustained low temperature to Kentucky and Tennessee. The extent of this cold weather period can best be described by quoting some excerpts from a bulletin (*1*) published by the Tennessee Valley Authority:

> Following and during the heavy snow of Feb. 14–16, temperatures declined to the lowest in several years and a warming trend did not begin until Feb. 21.
>
> The US Weather Bureau reported that Tennessee had the coldest February average temperature in the eastern section since 1895, and since 1905 in the western portion of the state; North Carolina [had] the lowest average temperature at most points since 1934, and a new record low temperature for the state [was recorded] at Clingman's Dome Peak of −23°. Alabama had the coldest February over most of the state since 1895, but no new absolute temperature records were set. Memphis' mean temperature of 34° was the third lowest for February, the record being 32° in 1899. Chattanooga's minimum temperatures on Feb. 17–20 broke records for lowest temperatures for those dates since records began in 1879; and at Knoxville, this month was the second coldest February of the 88 years of record. New record minimum temperatures for the date set were on Feb. 17, 18, and 19. At Asheville, this month was the coldest February of rec-

ord and the minimum temperature of −3° on Feb. 17 was the lowest ever recorded for so late in the season.

A most spectacular ice condition developed on some 3 mi of the French Broad River at Marshall, N.C., on Feb. 17, when drift ice and mush ice froze solid from bank to bank. Water backing up through the storm sewers flooded several blocks of Main Street in the center of town to a depth of some 6 in. These waters receded in about 3 hr, but a similar occurrence was repeated on the 18th and 19th as the current sought to free itself from the restraining ice. The ice, which in some places had jammed to a depth of 13 ft, was a threat to the bridge spans for some 5 days; however, by the 24th the channel had cleared itself without further incident. No significant damage resulted from the flooding.

Knoxville's February Freeze

Between Feb. 17 and 25, 1958, the Bureau of Water handled 2,034 complaints. There were 1,125 "no water" calls—113 frozen service lines, 469 frozen pipes on private property, and 543 frozen meters. There were 78 main breaks and three frozen mains.

The number of service calls for meter and service leaks, shutoffs, and turn-ons amounted to 909. Approximately 750 meters, or about 1.5 per cent of the total, were damaged. Slightly more than 1 per cent were actually frozen and had to be removed. Approximately 0.3 per cent of the active service lines froze. The three frozen mains were all 2-in. mains.

Preventive Procedures

It is possible to plan and construct a water system to such standards that there would be practically no operating problems due to freezing weather. Such a system would, however, involve tremendous expense in original cost and in routine operation and maintenance. In this respect, each designer or operator must determine what optimum standards or procedures to follow, consistent with the expected cold-weather pattern in the locale, and consider the economics of deviating from this norm. These procedures are usually determined by direct experience or the experience of existing successful installations in the immediate area, and usually involve a calculated risk with regard to extreme or sub-zero temperatures of several consecutive days' duration. The system should certainly be constructed to standards that are sufficient to protect the facilities during normal freezes and should have a reasonable safety margin below that point.

Underground Facilities

In Knoxville the general depth standards that have been established for the protection of underground facilities are: service lines and meters, normally 24 in. with an absolute minimum of 18 in.; 2-in. pipe, 24 in.; 6- and 8-in. pipe, 3½ ft; 10-in. and larger, 4 ft, if possible. The depth of 6-in. and larger pipe is governed by conditions other than frost protection, because it is installed at depths where frost penetration is not a factor.

Standard operating procedures for extremely cold weather are the result of experiences over many years, and are those that have been found to be most adaptable, economical, and expedient.

Equipment and Tools

Needless to say, all work and maintenance equipment should be checked, serviced, and winterized prior to the freezing season. All mobile and power equipment should be available for duty under all conditions. Tire chains

should be readily available for all vehicles. During extremely cold weather it is highly advantageous to store items such as air compressors, portable pumps and generators, and other power-driven equipment in a heated or otherwise protected enclosure. This helps to insure quick starting of engines and availability of the equipment when it is needed.

The supply of power and air tools should be ample and in good working order. Small hand tools and special items such as turnoff or curb cock keys, meter wrenches, or other special wrenches should be on hand in sufficient quantity to supply additional emergency crews. Extra street barricades, red lanterns, or other warning devices should be available.

Supplies and Materials

A sufficient supply of repair materials of all types should be readily available. These materials should include pipe, pipe repair clamps, repair sleeves and couplings, water service repair materials, provisions for inserting bypasses in metered connections, and meter repair parts.

When ice forms on the street surface after water escapes from a broken main or service, a supply of sand should be available to be scattered over the ice. When confronted with this possibility, the Knoxville system has found it advantageous to keep dump trucks loaded with sand and in a heated enclosure. The sand truck can be dispatched immediately after the emergency crew to lessen the hazard and liability of ice formation caused by water escaping onto the streets or sidewalks.

Personnel

Regular operating and maintenance personnel are usually able to cope with the situation with the available work forces and equipment normally assigned to their function. If additional help is needed, work forces of the system normally assigned to construction work may be called upon to render assistance. Inexperienced personnel are of little value in a period of emergency. If the situation warrants the action, the combined crews are put on a regular 12-hr rotational basis and may be called upon to work additional overtime to the extent required. The work schedule is governed by the work load.

Main Breaks

Extremely cold weather usually brings a higher frequency of broken or ruptured mains. This is evidently caused by additional stresses in the pipes induced by rapid temperature changes in the water. The soil or other fill medium surrounding the main becomes colder. In the Knoxville surface water supply, the water passing through the mains may change in temperature quite rapidly. Stresses which are caused by lengthwise contraction of mains are cumulative or add to the existing stresses due to internal pressure or other stresses present in the pipe and cause tension breaks. These breaks are generally characterized by being circumferential. A line of fracture that is perpendicular to the center axis of the pipe section is an indication of excessive tension. Evidently this occurs more often when a section of pipe is restrained from lateral movement either by overburden, soil friction, or other means. There is also some slight loss of strength because pipe materials become more brittle at lower temperatures. The converse is true when there is an abrupt rise in

temperature; the breaks then caused are the result of extreme compression at the point of rupture. It is therefore evident that complete protection of the pipe from external freezing conditions will not entirely eliminate breaks if the water flows through the pipes too rapidly and is subject to severe temperature changes.

Repairs to Mains

Repairs to broken mains must be given high priority; consequently the crews performing this work ought to be supplemented if conditions warrant it. Minor repair or operating work that they may normally perform should, if possible, be assigned to others during such emergency periods.

Freezing of noncirculating mains subject to exposure can often be prevented by opening the blowoff connection at the dead end and allowing the water to flow constantly during extremely cold weather. This should be normal operating procedure on mains suspended from bridges and culverts or in other locations where they cannot be adequately protected. This measure will also help to protect temporary mains or other pipe that is known to have insufficient cover.

Electric-Resistance Thawing

In Knoxville the method of applying electric current and utilizing the heat created by electrical resistance to thaw mains or services has been attempted during previous freezes with varying results. The amount of current necessary to thaw sections of frozen pipe by resistance is relatively large and can be hazardous under certain conditions. The rubber rings in hydraulic coupling joints can be severely damaged by this process, especially if the couplings are not armored and do not permit passage of the current through metal. A neighboring water utility that attempted this resistance technique reported that there was difficulty with iron rust and scales that were loosened in small-diameter steel pipe. The red-water complaints were as bad as the difficulty caused by the frozen main.

Proper Installation

The best protection against freezing of mains and services is to install them at a reasonable depth for protection. The few frozen mains that Knoxville has had recently have been located in a portion of a small system which was annexed to the city's system. The mains that froze either were originally installed at too shallow a depth or street-grading operations had subsequently removed some of the cover. As soon as such a condition is discovered, the mains should be scheduled for lowering or replacement. Sometimes the discovery is not made until freezing has actually occurred. When this happens it becomes necessary to thaw and restore the frozen section under the worst possible working conditions. (In this connection, it should be noted that frozen fill or spoil should not be used for backfill.)

The author has come to the conclusion that the best thawing equipment is a small, self-contained, gas-burning steam generator. The amount of heat applied in a meter well can be controlled, and the generator can be used near a meter without excessive risk.

Frozen Meters and Services

At Knoxville the water meters and water service lines are usually more susceptible to freezing than the other water appurtenances installed by the utility. Yard or curb meters are standard in the region. It has been the

practice to set the meter at least 24 in. deep at the base line. This depth is ample for protection under average soil and exposure conditions. The kind of meter used has shear sections in the bottom lugs or bolts which secure the bottom or base of the meter. Results with this type of meter have been good.

During extremely severe weather when it is possible that some meters could freeze, a supply of ¾-in. pipe nipples cut 7¼ in. long is made up and kept on hand for insertion in meter settings when meters are removed. Most of the ⅝-in. meters have a meter setting that permits easy removal of the meter without disturbing the connecting pipe. This enables service to be restored immediately on the customer's line. The use of bypasses is resorted to only if a replacement meter is also likely to freeze when installed at the same location. The decision as to whether or not to start using bypasses at meter installations is governed somewhat by the severity and expected duration of the freeze, availability of replacement meters, and past experience in similar freezing conditions.

A special record should be made of any installation that is known to have frozen. If the installation is not lowered at the time of the emergency repairs, it should be inspected and necessary remedial measures taken as soon as possible to avoid a possible recurrence of the trouble.

Care must be exercised in the storage and handling of meters not in service. A meter may freeze on the service truck if not carefully drained. Where it is the practice to test new meters and repaired meters prior to storage, it is difficult not to leave a small amount of test water inside. The practice recommended by most meter manufacturers is to store meters upside down. Meters in storage should be kept in an enclosure that will protect them from freezing.

A quantity of meter bottoms or bases and bolts should be readily available for the meters to be repaired. At Knoxville a large number of nonoperating meters reported by meter readers immediately after a freeze require replacement of one of the gears in the intermediate gear train. This is probably caused by freezing of moisture in the register assembly only, thus allowing the meter to continue to operate and damaging a gear tooth.

Hydrants

Hydants should be inspected at least once a year to insure proper operation. This work should always be completed prior to freezing weather. One of the most important checks to make is that the hydrant drains properly immediately after closing. Knoxville uses the dry-barrel compression hydrant. The depth underground is 3½ ft.

Hydrants known to be operated frequently during the winter may require additional inspections. If the street crews use certain hydrants regularly to fill street-washing trucks or to flush sewers, these hydrants may require special attention and inspection. A simple method of determining whether the hydrant is completely drained is to remove the hose or steamer cap and tie a heavy nut or other object to a strong string and lower it into the barrel. By knowing the depth of the barrel to the valve, one can determine whether ice has formed. If the string is wet, water is present and there is a possibility of freezing.

Sometimes hydrants are mistakenly thought to be frozen in extremely cold

weather because the operating stem sticks or seizes in the bonnet gland packing. This seizing of the stem may be caused by the small amount of moisture or condensation sometimes present in the bonnet section around the gland. Firemen should be instructed to expect this condition occassionally. A small ring of waste or packing saturated in kerosene, placed around the operating nut or bonnet shield and ignited, will thaw out the gland immediately.

Customer Service

In the Knoxville system all mains and other water facilities located in the public street are owned, operated, and maintained by the water department. Service lines are maintained up to the property line but the department does not perform work on the customer's property. If a customer has need for turning the water service on or off to make repairs, this is done without charge.

All incoming trouble calls or complaints relating to maintenance or operation are taken by a dispatcher in the operating division, who then makes a record of the information. This dispatcher assigns the work to the proper crew for attention. Communication of these orders to the crews is usually by two-way radio. The short-wave frequency is shared with the gas bureau of Knoxville's utilities board. This arrangement has proved highly satisfactory.

The greatest number of trouble calls during freezing weather are from customers requesting that their service be turned off because of frozen or burst pipes on their property. Often a customer is alarmed by the damage being done inside his home. The most important thing to him at the time is immediate action on the part of the water utility to turn the water off. Few customers know how or attempt to operate the property shutoff valve. In Knoxville, two-man crews in radio-equipped vehicles perform this work. If the frequency of calls is extremely heavy the city is divided into approximately equal work loads or sections. The trouble dispatcher will then keep one crew working in a certain quadrant or section of the city. This decreases the distance and hence the time required for the crew to reach the customer. Distance is usually a very important factor because extremely cold weather may be accompanied by frozen snow or ice on the streets.

Additional personnel are used when necessary without the benefit of radio equipment. The men report back to the dispatcher by telephone as soon as the previous trouble calls in their assigned area have been completed.

Frequency of Service Calls

Experience has shown that if temperature conditions run true to pattern, the greatest frequency of shutoff calls occurs during the two periods 4:30–8:30 PM and 6:00–8:00 AM. The afternoon rise in call frequency is probably because many people are at work during the day and discover the trouble upon their return. The early-morning rise in call frequency is undoubtedly attributable to discovery of the trouble when the customers arise and to the fact that the extremely low temperatures encountered usually occur at about sunrise. Duty hours of personnel handling these service calls must be adjusted to meet these peaks.

A great number of shutoff service requests are not received until after the weather has warmed up. These

calls are usually from persons with yard faucets in which the sillcock or pipe riser was frozen solid but gave no indication of rupture until after thawing began. Sometimes infrequently used laterals or branches from the principal service line will be frozen but not give any difficulty until the thaw starts. The beginning of the thaw period generally creates a greater total work load because the thaw shutoffs are superimposed on requests for turn-ons from customers who have been able to effect their plumbing repairs.

Plant Problems

Problems of freezing in the operation of pumping and filtration facilities are usually minor in this particular region if the plant is properly designed and operated. It is not exceedingly expensive or difficult to eliminate most of the risks of freezing.

In some instances there may be some difficulty with anchored ice in exposed basins or tanks. Damage to baffles, weirs, or other facilities may result if ice anchors to such appurtenances and if there is a subsequent change in the level of the water supporting the ice. Either the ice must be kept broken up or the water level must be held at a nearly constant level.

Additional heat must be applied to liquid-chlorine cylinders and to gas chlorinators to maintain operating pressures. There is some loss in the efficiency and reaction time of the chemicals, especially alum, at lower temperatures; hence a greater amount of suspended matter may reach the filters.

Risers, Gages, and Instruments

There are always some devices or appurtenances that may be overlooked from the standpoint of freezing protection. Among these are recording or indicating pressure gages on outdoor installations. If electric power is available at the installation, consideration should be given to the permanent installation of small resistance strip heaters in an enclosure with the gage or device. These heaters also serve to keep down moisture around precision equipment. If electric power is not available at the location, provision should be made for an ordinary kerosene lantern, or several of them, during extremely cold weather.

Gage lines or pilot lines may sometimes be exposed with no reasonable or economical way to protect them. There are several types of electric heating wire that can be wrapped around the exposed pipe.

Water level–indicating floats and float switch controls should not be located too near the wall of exposed tanks where ice may form. In small tanks it may be possible to use a probe to break away the ice on the surface of the water if ice interferes with the operation of floats.

Small-diameter risers to elevated tanks should be jacketed and insulated. If the riser is 12 in. or less in diameter there is a probability of solid freezing during prolonged periods of subfreezing weather.

Conclusion

Although the Knoxville water department is aware that it was unable to protect all of its facilities as well as it might during the February 1958 freeze, the procedures that have been described were able to minimize the effects of what might otherwise have been a crippling circumstance. These procedures, which have been devel-

oped over a period of years, worked so efficiently that the author is satisfied that their continued use is warranted, unless future winter freezes indicate that the frequency of low extremes is increasing.

In the light of what has been learned from these experiences, Knoxville should be able to face another occurrence of an extended freeze with inincreased confidence. It should be emphasized that the most important factor in operation under emergency conditions is the wholehearted cooperation of competent supervisors and personnel. It is to these people that full credit should be given for a job well done.

Reference

1. Precipitation in the Tennessee River Basin, February 1958. Report No. O-243-275, Tennessee Valley Authority (Feb. 1958).

Discussion

John M. Burka

Engr., Fountain City Utilities Board, Fountain City, Tenn.

The methods and suggestions presented in this article for maintenance of service in extremely cold weather are sound and can be effectively utilized by all water utilities regardless of size.

Although Fountain City, Tenn., is adjacent to Knoxville and had its own share of burst meters and frozen meters, mains, and service lines, damage was not as extensive as it was at Knoxville, because of the relatively warm, well and spring water supply. Knoxville's surface supply temperatures were hovering above the freezing mark, but the well water temperature at Fountain City was approximately 57°F. This warmer water protected all of the looped mains and services from freezing; troubles came only from shallow, dead-end mains and poorly protected services.

Customer Service

Troubles that caused customers' service complaints were approximately 50 per cent of the utility's responsibility and 50 per cent the customers' responsibility. Service troubles consisted predominantly of frozen meters and burst meter bottoms. These failures were easily recognized as being: 30 per cent due to inadequate fill and improper meter bowl installation, 30 per cent due to poorly fitting meter lids or rocks and dirt beneath the lid, 20 per cent due to broken meter lids and bowls, 10 per cent on vacated property where no water was used, and 10 per cent due to no evident cause.

The procedure used in restoring service where there was a frozen or burst meter was to replace the damaged meter and temporarily correct the improper installation. The original meters were afterwards reinstalled and the installations were subsequently corrected.

Frozen Mains

The frozen mains were all small-diameter, galvanized pipes and were easily thawed by means of a 300-amp welding machine. Frozen ¾-in. pipe was restored to service almost immediately after the application of current. Approximately 15 min was required to thaw 50 ft of 1-in. pipe, and 1½-in.

pipe required approximately 1 hr per 50 ft. Unfortunately, 2-in. pipe could not be successfully thawed with the 300-amp machine.

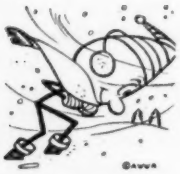
No problems were encountered in the use of this method of thawing frozen lines. All the necessary precautions were taken to insure that no sparks jumped from the customers' pipes into combustible material beneath the houses. There was an immediate temporary red-water condition caused by dislocation of the pipe scale by the heat, but this was easily remedied by blowing off the main, and the red-water condition did not recur.

Depth Standards

Main and service installation practices at Fountain City are in keeping with the accepted practices at Knoxville and other nearby utilities. Fountain City has adopted an 18-in. minimum-depth standard for service installations and a 3½-ft depth standard for main installations. At these depths and under the normal low temperatures for Tennessee, the mains and services are adequately protected. Absolute protection against freezing by deeper laying of mains is too costly from an installation, operation, and maintenance standpoint.

Conclusion

Continuity of service is expected by water customers today; as a result, both the water utility and the customer must make preparations for winter. Fountain City has, in the past, mailed out winter reminders to its customers, recommending that they examine exposed plumbing, especially outdoor spigots, and install proper insulation against cold. The utility must also examine mains and service lines to insure that none have been exposed by erosion or road work. This examination can be combined with the normal meter reading during the fall season.



Location and Evaluation of Ground Water Resources

Lynn M. Miller

A paper presented on Sep. 18, 1958, at the Ohio Section Meeting, Cleveland, Ohio, by Lynn M. Miller, Ground Water Geologist, Jones, Henry & Williams, Cons. Engrs., Toledo, Ohio.

THE location and evaluation of ground water resources require the application of both geological and engineering techniques. Typical examples of the coordinated efforts of geologists and engineers in dealing with ground water problems exist in the Ground Water Branch of the USGS, the parallel agencies of many states, and a few consulting firms. Most of the quantitative evaluation methods in common use are the products of such group effort. The USGS is usually given credit for the pioneer efforts and for the training of most ground water experts.

The purpose here is to discuss some of the principles of ground water location and evaluation in terms that will be meaningful to those who are not trained experts but are vitally concerned with adequate ground water supplies. For the sake of illustration, use will be made of a survey and evaluation problem for the area around the city of Wooster in Wayne County, Ohio. The Wooster survey is not unique but does represent a problem of greater than average complexity and interest which covered an area of several hundred acres.

Geology and Exploration

It has been estimated that 17 ft of the top 100 ft of an average land mass is water. This is disseminated water that fills the voids between the grains of unconsolidated and granular rock and the cracks and fractures in dense rock formations. Most of this water is moving slowly toward a point of discharge. Over the period of a dry summer, ground water levels usually decline as water drains to streams and lakes or is pumped from the ground through wells. During periods of greater precipitation, a portion of the rain and snow waters gradually trickles into the ground to saturate it once again, and water levels rise. The earth's crust may be considered as a giant reservoir. It is not a simple tank with the usual definite physical proportions, however. The total reservoir capacity is the sum of the capacities of the countless small voids within and between the fragments of earth materials.

The geological history of a region determines the manner in which materials are deposited and, in turn, the types of material which are located in different areas of the region. Further evaluation of the materials within an area requires study of available well records, drilling of test wells, and evaluation of reservoir capacities by water production methods.

Designing a program of exploration that will yield a maximum of informa-

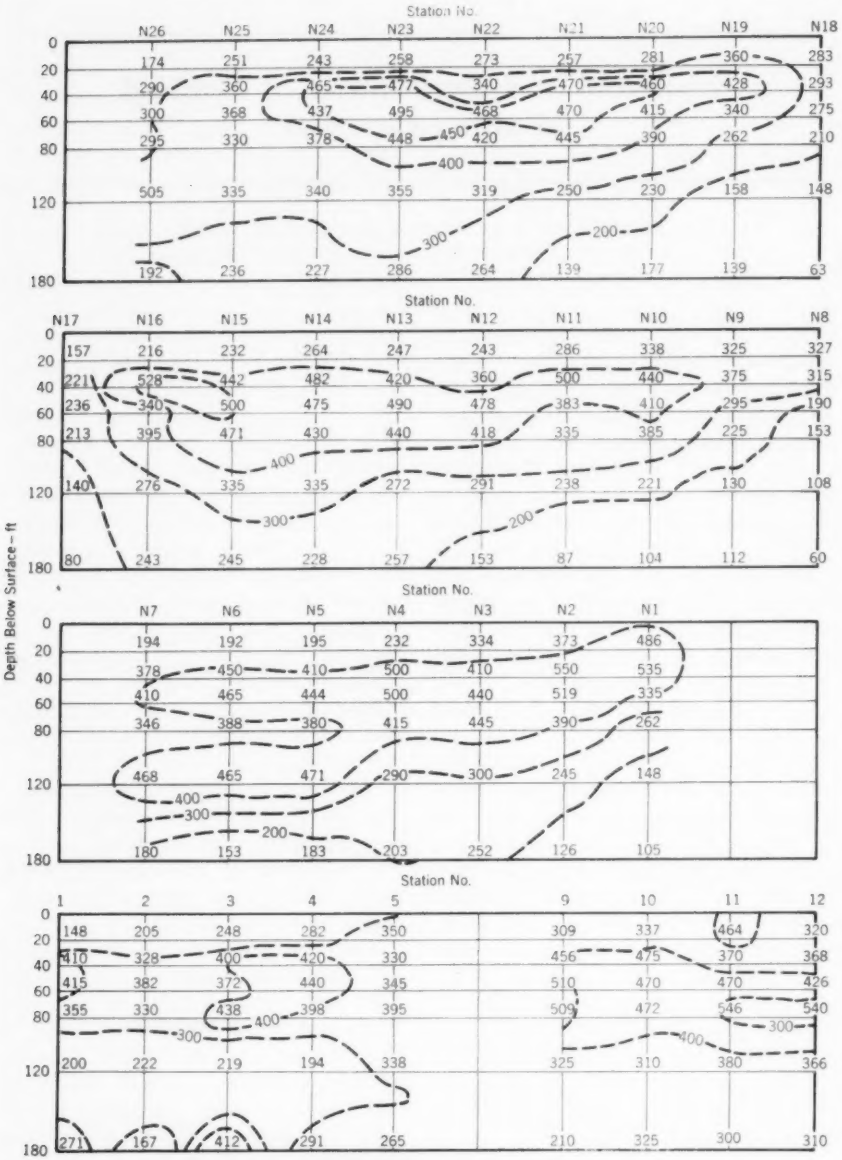


Fig. 1. Resistivity Cross Sections

By plotting data such as these, gathered by the method of electric resistivities (described in text), and correlating them with plots such as those of Fig. 2, a good general three-dimensional picture can be formed of the geologic strata within a given area.

tion for reasonable expenditures requires a careful evaluation of the geology, available drill records, and size of available areas. It is often profitable to use some means other than extensive test drilling to determine the general subsurface conditions. Electrical resistivity surveying is one supplemental method that has been used with reasonable success in areas where glacial action has been responsible for much of the surficial deposition. It is necessary to use both electrical resistivity surveys and test drilling program to develop a proper and comprehensive survey.

The fact that different earth materials exhibit different resistances to an electric current provides the basis for the electrical method of detecting changes in deposition. The electrical survey is conducted by placing four electrodes, at equal intervals and depths, in a straight line and passing a current between the two end electrodes while the drop in potential is measured across the inner pair of electrodes. From the data thus obtained a resistance value, which is called "apparent resistivity," can be calculated. The apparent resistivity is an average resistance presented by all earth materials from surface down to the depth of penetration. The depth of penetration is approximately equal to the interval between electrodes. By keeping the center of the electrode array at a fixed point and repositioning the electrodes at various intervals, one may compile data and calculate an electrical relationship of materials in a vertical section. If the process is repeated for a number of points in an area, a horizontal cross section can be constructed which is easily contoured to show the general stratification of materials. Figure 1 shows resistivity cross sections which illustrate the technique. Figure 2 shows the locations of 35 resistivity stations run during the course of the work at Wooster, Ohio, and illustrates another method of presentation. In this figure the average electric resistances, for a constant interval of electrode spacings, have been contoured in the same way that a topographic map would be constructed. By comparing the results of both presentations, a three-dimensional picture of the reaction to an electric current can be developed.

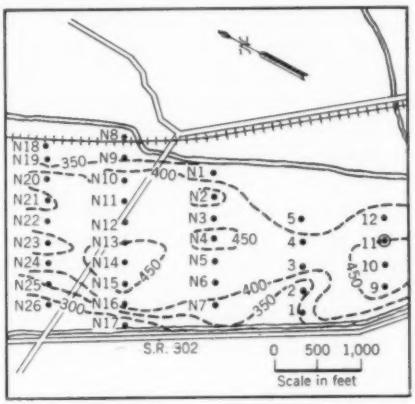


Fig. 2. Resistivity Contours

These contours represent a second method of plotting the same resistivity data as plotted in Fig. 1.

The application of this electrical picture to the geology and ground water potential of the survey area is a matter of correlating the various ranges of resistivity values with the earth materials they represent. In general it has been determined by practical field investigations that the well sorted, permeable, granular formations have a higher resistivity range than do the poorly sorted and clay materials. This is true if all materials are saturated with water.

Reservoir Evaluation

When a test drilling program confirms the presence of water-bearing materials, it becomes necessary to determine how much water may be withdrawn and at what rates. Several factors, which are not directly measurable, determine the effects of pumping from a water-bearing formation, or aquifer. For example, 1 cu ft of uniform sand and 1 cu ft of well sorted gravel will have nearly the same volume of unoccupied spaces. However, if these two units of material are thoroughly mixed, the sand particles will fill in much of the interstitial pore space of the gravel, and the volume of the mixture will be considerably less than 2 cu ft. If a third unit of another material size is mixed with these, the volume will be less than 3 cu ft, and there will be an even smaller amount of open pore space. Thus, the greater the variety of grain sizes in a formation the less pore space and reservoir capacity there will be. Also, it is evident that the large, open, and well connected pore spaces of a uniformly coarse gravel will permit fluid flow with less head loss than would small pore spaces in a fine sand or irregular and poorly connected pores of a material composed of many grain sizes. The measure of a formation's ability to permit the movement of water under given head conditions is called its permeability. Thus a formation can have a high porosity but a low permeability compared to another.

The properties of porosity and permeability for a particular aquifer can not be accurately measured by test drilling or resistivity surveys. But drilling samples do indicate the average thickness and degree of sorting represented by the resistivity values, which in turn yield some knowledge concerning the distribution of these conditions.

Because permeability and porosity are terms developed for application to definite volumes of material in laboratory work, they are of limited value in field applications where conditions are irregular and only averages can be measured and calculated. For field use, the product of the permeability of an aquifer and its average thickness is called the coefficient of transmissibility (T). The ability of a formation to store and yield water is most nearly related to its porosity and grain size and is called the coefficient of storage (S).

Determining these coefficients by any means other than actual tests in the field is expensive, time consuming, and of questionable accuracy. Field testing methods for determining these coefficients have been developed and are most popularly presented as the Theis nonequilibrium formulas (*1*). These methods are thoroughly discussed in the literature on the subject and have been further discussed by many JOURNAL contributors. In developing the method, Theis found it necessary to make certain basic assumptions, some of which are rarely satisfied in nature:

1. The aquifer is isotropic and homogeneous
2. The aquifer has infinite areal extent, and is of uniform thickness
3. There is uniform radial laminar flow toward the pumping well
4. There is instantaneous release of water from storage with no leakage from adjacent beds
5. T and S are constant factors.

A modification of the Theis method is attributed to Jacob (*2*) and employs the principle that under constant-rate pumping the drawdown for any well

influenced is directly proportional to the logarithm of elapsed time.

When a formation being tested is of great extent and of relatively uniform composition, the water level curve, for all wells, when plotted against the logarithm of elapsed time will approach a straight line. Further, the straight-line portions of the plots will have the same slope. Since the numerical expression for this slope represents the denominator of the Jacob expression for transmissibility (*2*), it is evident that the uniformity of a formation's ability to transmit water can be checked by comparing the plots for an array of observation wells.

It should be noted that the T so determined for any one observation well represents the average condition between the observation well and the point of pumping. Therefore, in a formation of variable composition, it should be expected that each observation point will yield a different value for T. It is common practice to average the T values thus obtained for use as a design factor.

When a formation is discontinuous (Fig. 3), the condition of great areal extent is no longer satisfied and production demand per unit area upon the limited formation is increased in the direction of discontinuity. The effects upon the water level in the formation resemble those that would be produced if another "image" well were pumping an equal quantity at an equal distance beyond the boundary. Thus, the rate of drawdown at all wells is increased.

If the formation is continuous but is intersected by a stream, lake, or other source of recharge (Fig. 3), the effects will be similar to those produced by injecting water into the formation at a distance beyond the source equal to its distance from the area of pumping. Thus a reduction in the rate of change in water levels will be detected at all points of observation.

When formation boundaries lie at a sufficient distance from the pumping well and points of observation, the straight-line plot will be established prior to the appearance of boundary effects. In such cases the boundary distances can be determined by the use of an equation similar in form to:

$$\frac{r_0^2}{t_0} = \frac{r_1^2}{t_1} = \frac{r_2^2}{t_2} \cdots \frac{r_n^2}{t_n} = C$$

where

r_0 = distance from the pumping well to the observation well

r_1 = distance from the observation well to the first image (twice the distance to the first boundary encountered)

r_2 = distance from the observation well to the second image (twice the distance to the second boundary encountered)

r_n = distance from the observation well to the nth image (twice the distance to the nth boundary encountered)

t_0 = the time at which the straight line plot of data intercepts the value, $D = 0$ *

t_1 = the time at which the effects of the first image occur on the data plot

t_2 = the time at which the effects of the second image occur on the data plot

t_n = the time at which the effects of the nth image occur on the data plot

C = a constant.

*[Jacob (*2*) uses "*s*" for this symbol (meaning "drawdown").—Ed.]

When the distance to a boundary has been determined for each observation well, arcs with a radius equal to these determinations can be swung; their intersection will approximate the position of the image interference. If no intersection of arcs occurs, it may indicate the presence of undetected, closer boundaries. This may be substantiated by an inspection of the data plots and range of T values.

Glacial and water-deposited materials usually exhibit a complexity of deposition which is reflected in their hydraulic responses. These responses may take the form of absolute boundaries but usually present a more complex picture of partial boundary conditions. The net effect may be rather suddenly established if the formation changes are at a distance from the pumping well that is great compared to the distance of the observation well from the pumping well. If these aquifer changes lie close to the pumping well, however, the time point of change may be extremely difficult to detect. In either case, if pumping rates

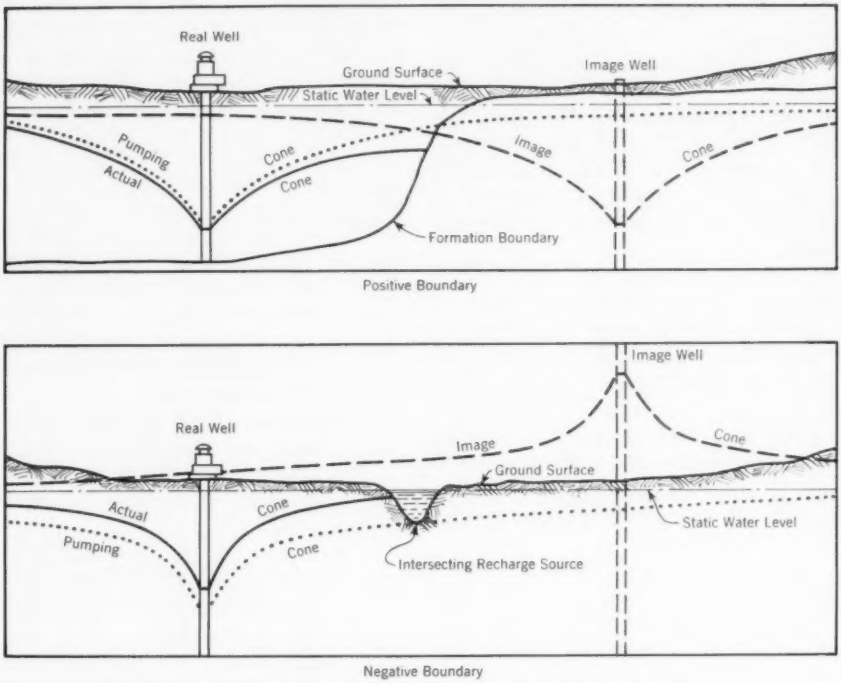


Fig. 3. Influence of Formation Boundary on Drawdown Cone

When a formation is discontinuous, Condition 2 of the Theis assumptions is unfulfilled, and the effects on water level are as shown in the upper illustration. When the formation is continuous but intersected by a body of water, conditions are as shown in the lower illustration.

and periods are of sufficient magnitude, the rates of drawdown for all points of observation will approach a straight line plot which can be utilized for a graphic rate analysis independent of calculations involving the coefficients T and S.

Evaluation Example

The unconsolidated glacial deposition in the preglacial-bedrock valley system of the Wooster area is typical of the more important ground water reservoirs in Ohio. The procedures employed in evaluating the area are good examples of the methods used in appraising ground water reservoirs.

From the test drilling and resistivity survey work in the Wooster area, it was known that the valley fill materials were quite variable, ranging from well sorted, thick gravels to thin, poorly sorted lenticular deposits of sand, gravels, and clay. Therefore, it was expected that a number of boundary conditions would complicate the analysis. Two aquifer tests were conducted using the test wells for pumping and observation. Figure 4 shows the relative position of these wells. In test No. 1 the pumping rate was 1,500 gpm for a period of 2 days and in test No. 2 the pumping rate was 2,800 gpm and the pumping period 3 days.

For test No. 1 all plots showed a decided increase in slope from about 300 min on (Fig. 5). No indication of this was detected on the plots for test No. 2 (Fig. 6). An increase in recovery slope is indicative of formation recharge.

The greatest apparent rates of water level change for each observation well used in tests No. 1 and 2 are given in Table 1.

The Jacob equation (2), $T = \frac{264Q}{\Delta D}$, indicates the rate of drawdown (ΔD)

TABLE 1

Apparent Rates of Water Level Change for Test Wells

Pumping Rate gpm	Recovery Rate per Logarithmic Cycle ft				
Test No. 1					
	Well 6	Well 7	Well 8	Well 9	Well 11
Before recharge					
1,500	2.22	2.20	2.10	2.05	2.26
1,000	1.48	1.47	1.40	1.37	1.50
With recharge					
1,500	1.25	1.15	1.15	1.06	1.27
1,000	0.83	0.77	0.77	0.71	0.84

Test No. 2						
	Well 8	Well 11	Well 15	Well 16	Well 17	Well 18
2,800	1.67	1.78	2.05	2.15	2.05	1.95
1,000	0.60	0.64	0.73	0.77	0.73	0.70

is directly proportional to the rate of pumping (Q). Therefore, to facilitate proper comparison, all rates of change were revaluated to a rate of 1,000 gpm. The adjusted rate values for test No. 1 and test No. 2, after recharge is established, show good comparative values. The decline rates for test No. 1 prior to the establishment of recharge are approximately twice this magnitude, which implies that images of formation discontinuity occur at relatively short distances from the pumping well.

From what was learned of the formation composition through other survey work, the boundaries of discontinuity should dominate the hydraulic characteristics of the formation. This is especially true for periods of drought when stream flow is at a minimum and water pumpage at a maximum. Therefore the evidence of formation recharge should be ignored; it should also be assumed that the formation is discontinuous, as shown by test No. 1, and that test No. 2 rates of change would have been equal to those in test

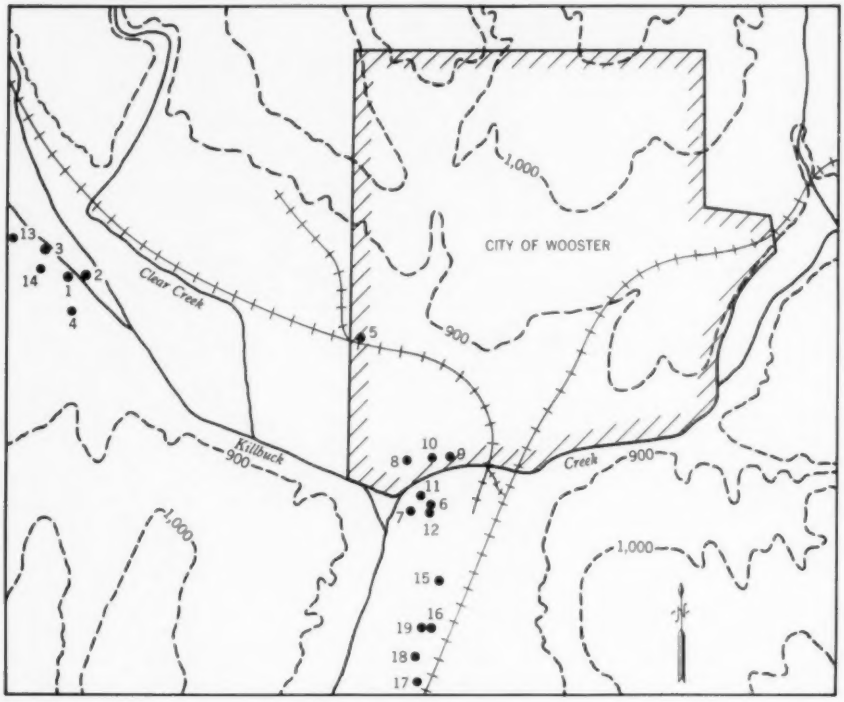


Fig. 4. Test Well Locations in Survey Area

Pumping data from the test wells shown above and application of the Jacob equation (2) using these data, aid in locating recharge and formation boundaries.

No. 1, had the test pumping period been extended.

Obviously the geologic analysis is not quite as simple as the apparent stated hydraulics. As long as satisfactory well sites can be located to produce the available water, however, it is impractical to seek a solution to the complex geologic picture.

In order to make use of rates of decline for well field design purposes, of the cone of depression at any given time after the true formation response has been established. Extreme boundary conditions may not permit satisfactory construction of such a plot because wells that lie close to the boundary are influenced to a greater degree than the field average. For purposes of design in a high capacity field over extended production periods, however, the consideration of the average effect

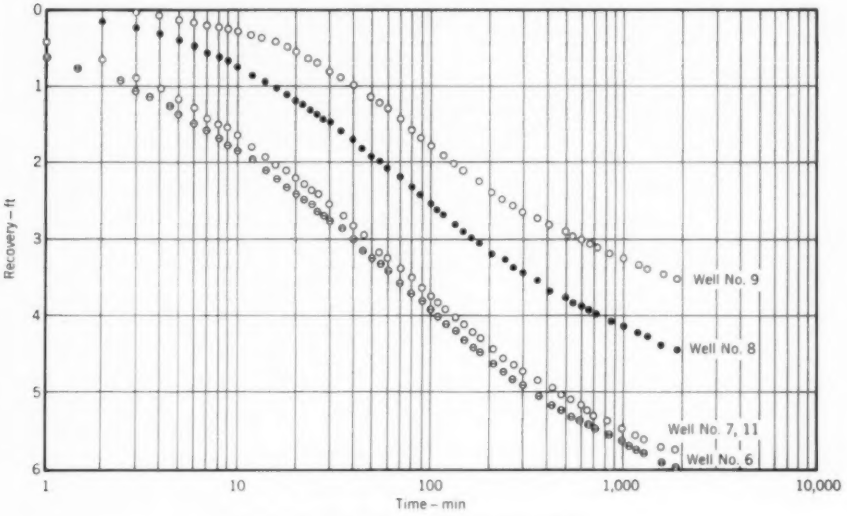


Fig. 5. Test Well Data for Test No. 1

The increase in slope for all wells after about 300 min indicates the presence of recharge.

it is necessary to establish what effects will be manifested during some time interval. Theim (*3*) has shown that the drawdown is proportional to the logarithm of the distance from the point of pumping. Therefore, by using observed data for a number of observation wells at different distances from the point of pumping it is possible to establish a logarithmic profile is of greatest significance. If pumping proceeds long enough, the points will nearly approximate the straight-line condition under the influence of most ordinary glacial formation changes. Figure 7 is such a profile and was constructed by adjusting the observed data from test No. 2 for various values of Q after a pumping period of 1,500 min, or approximately 1 day. Draw-

down is directly proportional to pumping capacity. For later convenience, the observed data were again adjusted to a pumping rate of 1,000 gpm.

From data in Fig. 7 the water levels at any point within the cone of depression of the pumping well may be forecast for the end of 1 day of pumping at 1,000 gpm. For example, at a distance of 500 ft from the point of pumping, the water level will have declined 1.36 ft per 1,000 gpm; at a distance of 1,000 ft the decline will be 1.04 ft per 1,000 gpm; and at a distance of 1,500 ft the decline will be 0.83 ft per 1,000 gpm. These values may then be used as a starting point for the construction of semilogarithmic curves of water level declines over an extended pumping period. Such curves are useful in estimating the capacity of a well field that has various well spacings, where the interference drawdowns of companion wells are a matter of concern. For the construction of such curves it is necessary to select the rate of decline to be used in extending the water level forecast. For the sake of conservatism, the effects of recharge should be ignored. The decline rate of greatest magnitude (1.5-ft logarithmic cycle) should be selected as the most conservative value. The curves in Fig. 8 are based on this construction.

When satisfactory approximations for T and S can be made without the

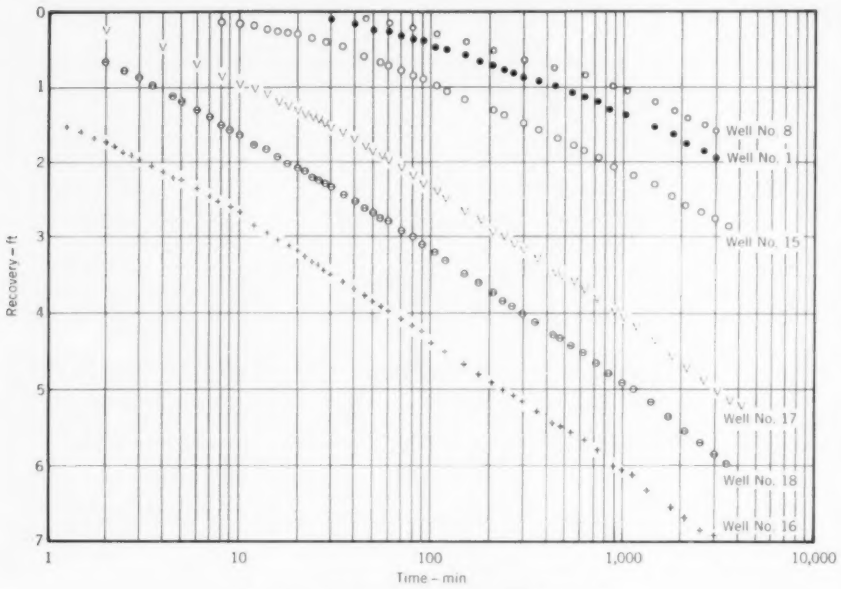


Fig. 6. Test Well Data for Test No. 2

The data plots for this set of test wells indicate no recharge present as in test No. 1 (Fig. 5).

influence of boundary images, these curves can be calculated with considerable accuracy. In cases where images appear at relatively short distances, the graphic-extension method provides a method of analysis which sacrifices a minimum of accuracy and is considerably more lucid than the complex and extensive multiple-image calculations.

Well Field Design

Drought periods of 100 days are not unknown in the Wooster area and represent a conservative estimate of the duration of heavy draft and limited recharge. If it is assumed that production wells at approximately 1,000 ft apart will have pumping capacities of 3,500 gpm each, and that pumping will be continuous for 100 24-hr days, then, where D represents drawdown and numerical subscripts denote the distance from neighboring wells, equations for total drawdown effects may be written.

For wells at end locations:

Total D (per 1,000 gpm)

$$= D_1 + D_{1,000} + D_{2,000}$$

When Q = 3,500 gpm,

Total D

$$= 3.5\ (D_1 + D_{1,000} + D_{2,000})$$

Substituting data from Fig. 8,

Total D

$$= 3.5\ (7.4 + 4.1 + 3.7) = 53.2 \text{ ft}$$

For a well at the center:

$$\text{Total } D = 3.5\ (D_1 + 2\ D_{1,000})$$
$$= 3.5\ [7.4 + 2\ (4.0)]$$
$$= 53.9$$

It must be recognized that the D factors thus calculated represent only that portion of the total drawdown which can be attributed to aquifer head losses under laminar flow conditions and interference effects of neighboring production wells. Additional head losses in and about a pumping well are factors for consideration in individual well design and beyond the scope of this article.

Long-Range Prospects

The estimates of drawdown have been made on the basis of aquifer characteristics displayed during a limited period of testing. It is therefore quite probable that results of long-term production from this area will be at some variance with those that would be predicted at this time. One factor of considerable interest is the rate of aquifer recharge that can be expected either through hydraulic connection to the surface streams in the area or by percolation of precipitation through the overlying soil and clay.

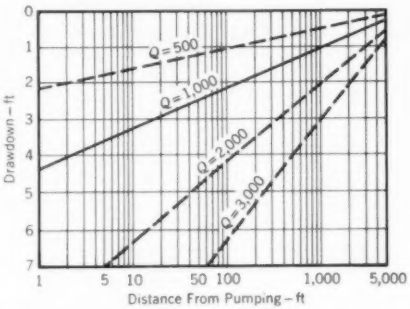


Fig. 7. Cone of Depression Profile After 1-Day Pumping

The curves represent logarithmic variation in drawdown with distance from the pumping well. Curve A, Q = 500 *gpm; Curve* B, Q = 1,000 *gpm; Curve* C, Q = 2,000 *gpm; Curve* D, Q = 3,000 *gpm.*

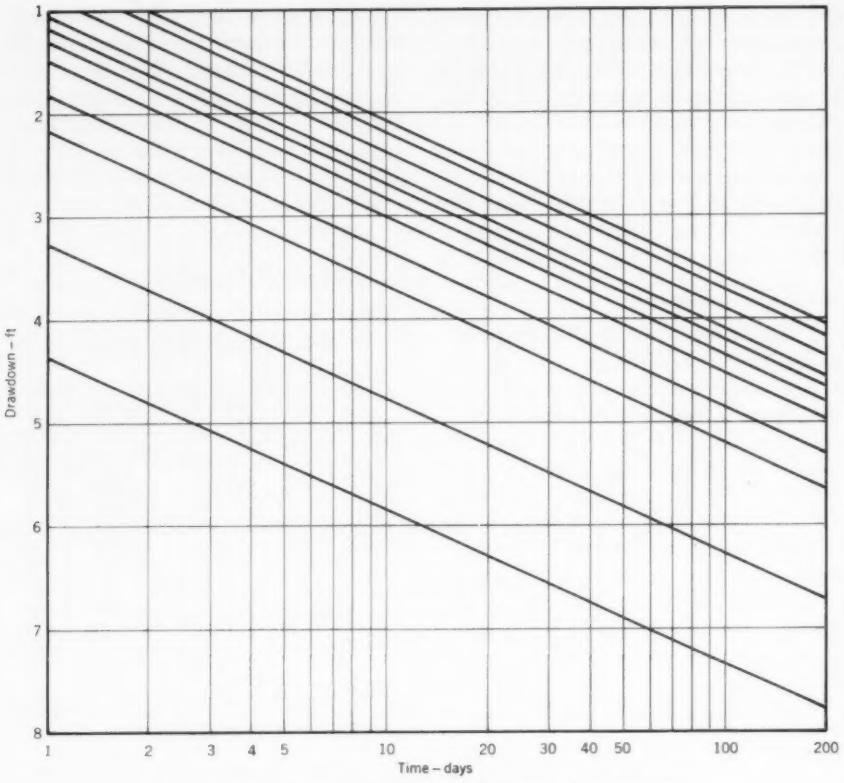


Fig. 8. Drawdown for Extended Pumping at 1,000 gpm

The curves above are based on the decline rate of greatest magnitude (1.5-ft logarithmic cycle) for various distances from pumping (Q = 1,000 gpm); distances are, from the bottom up, 1, 10, 100, 200, 400, 600, 800, 1,000, 1,500, 2,000 and 2,500 ft respectively.

Recharge rates have been determined in Ohio for the Miami Valley area and in Canton by USGS. For those two locations, the rates are, respectively, 650,000 gpd/sq mi and 374,000–460,000 gpd/sq mi. These figures refer to water table formations. There is considerable evidence to suggest that the Wooster area will assume water table characteristics during long-term pumpage. The total available recharge area to the aquifer includes the drainage area of Killbuck Creek and Apple Creek upstream from this point as well as a considerable portion of the valley downstream. This total area is greater than 200 sq mi. Using a recharge rate of 0.3 mgd/sq mi, to be on the conservative side, one finds that a production of 15 mgd from the well field would utilize the recharge of only one quarter of the area assumed to be

available and require a recharge rate of only 0.075 mgd/sq mi, or 0.08 gpd per acre.

Summary

Evaluation of geology and subsurface work prior to new exploration is the best basis for the selection of exploration areas in a region.

Electric resistivity and test drilling work should be coordinated to determine the best water-producing locations within an area.

Aquifer performance test work can best be evaluated by using the geological, electric resistivity, and test drilling data as a guide to the interpretation of hydraulic responses observed.

If large pumping rates are maintained over moderate test periods, it is possible to analyze test data without assigning absolute values for the coefficients of transmissibility and storage and estimate the interference of wells for the design of a well field.

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Relation of Long Island Ground Water Resources to Regional Needs

Joseph E. Upson

A contribution to the Journal by Joseph E. Upson, Research Geologist, Ground Water Branch, USGS, Mineola, N.Y.

IN the latter part of the nineteenth century and the early twentieth century Long Island was regarded as a large water-storage reservoir conveniently situated for the importation of water to Brooklyn and later to greater New York City. The chief problem was to determine how much water was available, although it appeared to be abundant. Accordingly, from 1896 to 1912 several investigations were made to determine the amount of water in Nassau and Suffolk counties, which constitute nearly 90 per cent of the total area of Long Island, that could be used elsewhere. Plans were made to use this water but not all the plans came to fruition. In 1942 there was established the policy of reserving for local use any ground water in Nassau and Suffolk counties not already appropriated. At present (May 1958) although external demands for Long Island's water have been largely eliminated local use is reaching large proportions, at least in some areas. In other areas water use in the next few decades may also be large. In fact, actual and potential uses are large enough to reach or even exceed the available supply. Close estimation of that supply and solutions to several critical technical problems, therefore, are needed even more urgently now than they were 50 years ago.

This article will describe briefly the general occurrence of ground water in the New York City metropolitan area, the relation of Long Island sources to the existing pattern of water use, what is known about Long Island's ground water, and finally some of the technical problems involved in full development of these ground water resources.

New York City

Figure 1 shows the New York metropolitan area, Long Island, and several surrounding counties. Five boroughs compose the city: Manhattan, Bronx, Kings (Brooklyn), Queens, and Richmond (Staten Island). According to the 1957 special census the population of the city was 7,795,471. This was a net decrease in population since 1950 of 96,486 (*1*). The population growth recently has been in the suburbs (*2*). The adjoining and nearby counties shown in Fig. 1 are more or less within the commuting radius. All of these counties have had a large percentage growth in population since 1950. The total population of the metropolitan area is about 15,000,000.

This population is supplied with water obtained locally or at no great distance, except for the population of New York City. As shown by a re-

port of the city's Board of Water Supply (*3*), about 75 per cent of the capacity of the city water system is derived from streams in the Catskill Mountains (some of the Catskill water is supplied to communities in Westchester County) and from the headwaters of the Delaware River, about 20 per cent from the Croton watershed in Westchester and Putnam Counties, and New Jersey. The area of low productivity is underlain mainly by relatively old igneous and metamorphic crystalline rocks and by consolidated sedimentary rocks. There is very little intergranular porosity in these formations and water occurs almost solely in fractures. The productivity of most wells that penetrate these rocks is small; the amount of storage water also

Fig. 1. New York City and Surrounding Area

The area covered in this article includes New York City, Long Island, and the surrounding counties. The population of this area is about 15,000,000.

and 5 per cent from local or nearby sources. Not long ago about 10 per cent of the city's water was obtained from Long Island.

Ground Water Occurrence

Figure 2 shows the generalized conditions of ground water occurrence in the metropolitan area and adjoining parts of New York State, Connecticut, is small. Throughout most of their extent the rocks are overlain by thin deposits of unstratified glacial drift which also produces only small amounts of water. This area has low ground water productivity even in relation to local needs.

The area of moderate productivity is underlain by partly consolidated sandstone and shale and some inter-

calated intrusive and extrusive volcanic rocks. The area of moderate productivity shown on the left of Fig. 2 is of Triassic age. The ground water productivity of these formations has a wide range, from very low for the volcanics to rather high for some of the less consolidated sandstones. At several places well yields are high enough to supply fairly large—but still local—needs. For example, the Connecticut General Insurance Co.'s offices near Hartford, Conn., and the city of Plainfield, N.J., are supplied with water from wells in areas underlain by Triassic, sedimentary rocks.

The areas which are most productive of ground water are underlain by unconsolidated, stratified, generally permeable deposits. The full thickness of these deposits in Connecticut, northern New Jersey, and upstate New York, and about the upper 200 ft in Long Island and Staten Island consists of stratified glacial drift, mainly sand and gravel. Not all the known areas of this type are shown by Fig. 2. Those shown within the other areas are the largest and are intended as examples. Actually, there are scores of smaller areas (*4*). In southeastern New Jersey and beneath the glacial deposits of

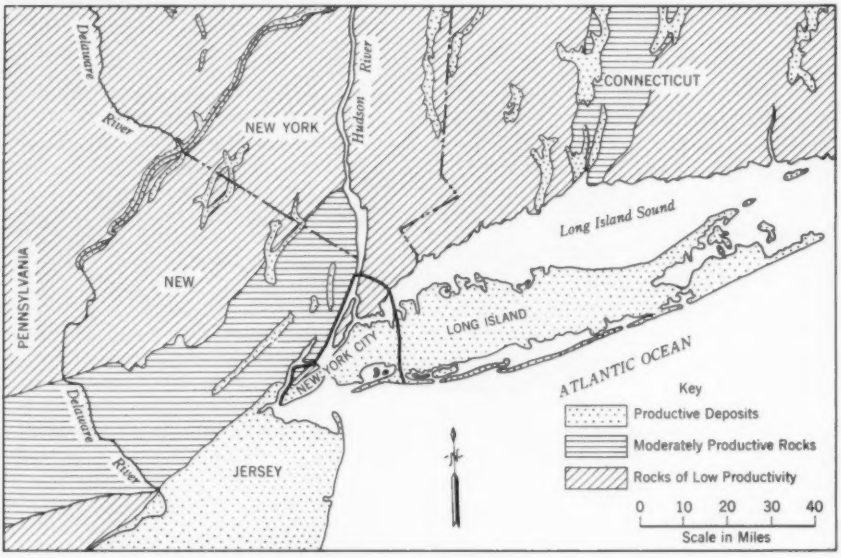

Fig. 2. Relative Ground Water Occurrence

The geology of the area covered in this article consists of productive deposits (unconsolidated, stratified, generally permeable), moderately productive deposits (partly consolidated sandstone and shale, intercalated volcanic rock), and rock of low ground water productivity (igneous and metamorphic crystalline, consolidated sedimentary rocks).

Long Island and Staten Island are unconsolidated continental and marine strata of clay, silt, sand, and some gravel of Cretaceous and Tertiary age. These deposits contain permeable zones which, in general, are capable of yielding large quantities of water to individual wells and of sustaining substantial and continuing drafts. Long Island and southeastern New Jersey contain the really large ground water reservoirs, potential sources of large quantities of water.

For more details on the general geology, as well as the extent, thickness, and water-yielding characteristics of the deposits in these productive areas the published literature should be studied. A recent report by Barksdale and others gives a rather full discussion of the same facts for New Jersey (*5*). Perlmutter and Arnow (*6*) have presented what is known about Staten Island. They also give some data on Kings and Queens, which are on Long Island, but a more comprehensive treatment of Long Island is given in the report by deLaguna and Perlmutter (*7*).

Ground Water Withdrawal

The relation of Long Island to the existing pattern of water use can be seen in the history of withdrawal of the island's water. Figure 3 shows the counties of Long Island: Kings and Queens in New York City, Nassau County with an area of 274 sq mi, and Suffolk County with an area of 920 sq mi, which is more than half the area of the island. The Long Island water supply installations of New York City, known as the Ridgewood System, are in southern Queens and Nassau County.

Ridgewood System

In the very early years of the settlement of the metropolitan area people relied upon springs, streams, and individual wells for water. In fact, the first public water supply in New York City was obtained from a well dug about the year 1677 at Bowling Green in southern Manhattan. On Long Island for a long time most people depended on individual water supplies. There have always been some individually owned private wells on Long Island (an estimated 40 per cent of the population of Suffolk County is still supplied from private wells) but in the populous area they have been replaced gradually by municipally or privately owned public water-supply systems. The replacement process started in the west end of the island, and spread eastward.

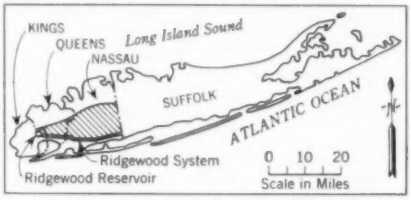

Fig. 3. Long Island, N.Y.

The shaded portion is the area of ground water catchment for the Ridgewood System. The Ridgewood System constitutes New York City's water supply installations on Long Island. The system has ponds, wells, and infiltration galleries along its conduit.

The first public supply system in Long Island was that of the old city of Brooklyn. When originally completed, in 1862, this system obtained water from surface streams between Brooklyn and Lynbrook (in Nassau

County), including the Hempstead supply pond. The water flowed by gravity through a conduit to Ridgewood where it was pumped into the Ridgewood Reservoir. By 1872 pumping stations were established on two other ponds that were too low to drain into the conduit by gravity.

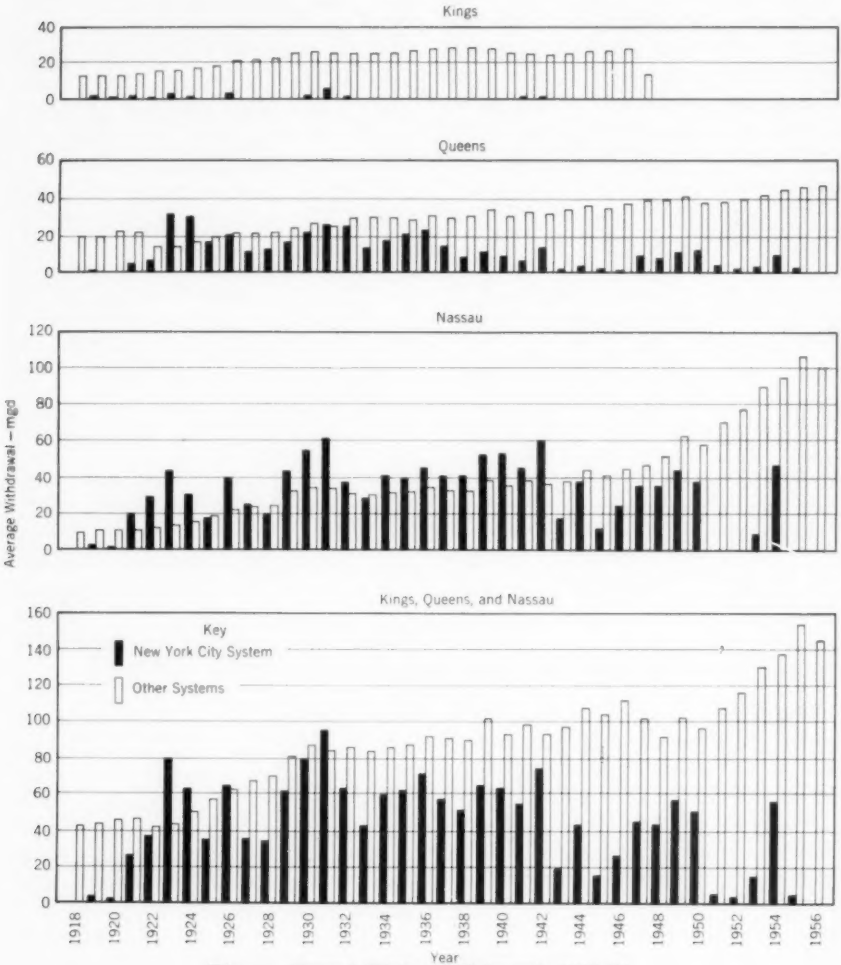

Fig. 4. Ground Water Withdrawal, 1918–56

The average daily withdrawals of ground water for public supply from Kings, Queens, and Nassau counties are shown. The withdrawals by New York City include some pond water which, after 1911, was all taken from Nassau. After 1920 pond-water withdrawal decreased to a small part of the total.

In 1872 a private system which drew water from springs was established at Sea Cliff in Nassau County. In 1874 municipal water plants were established in Queens at College Point, Flushing, and Long Island City. The Long Island City plant was based on a single, large well and was the first plant on Long Island to use ground water as the sole source of supply. In 1876 Garden City, in Nassau County, established a system depending on a single, large well. This well was dug 50 ft in diameter and 40 ft deep. It was retired from the system in 1956, after 80 years of service.

In 1880 the surface supply of the Brooklyn Water Works was supplemented by open wells at two pumping stations. In 1882 the first of a series of gang-well stations (shallow tubular wells pumped from a common header) was established at Spring Creek and Beisley; seven other stations were later established, the last in 1897 at Shetucket. In 1892 another pumping station was established at Millburn, a little farther east in Nassau County, and a conduit was extended from Smith's Pond to Massapequa, which is close to the Suffolk County line. By 1896 gang wells at five sites along this extension were being used; by 1903 the infiltration gallery at Massapequa was in existence and one at Wantagh (both in Nassau County) was in the process of construction.

These facilities came under the control of New York City in 1898 when Brooklyn and the other four boroughs were consolidated. These facilities subsequently became known as the Ridgewood System of the City of New York. According to Ward (*8*) the system's delivery to the Ridgewood Reservoir in 1899 averaged more than 92 mgd, of which about 80 mgd came from wells. More than half of this ground water was from Nassau County.

TABLE 1

Public Water-Supply Systems and Estimated Population Served in Long Island *

County	Populations†	Number of Systems in Operation‡		Estimated Population Served by Systems	
		Private	Municipal	Private	Municipal
Kings	2,602,433	0	—§	0	2,724,000‖
Queens	1,762,582	2	—§	563,000	1,724,000‖
Nassau¶	1,155,139	7	33**	506,500	679,580**
Suffolk	528,736	59	30††	50,000	241,500††
Totals	6,048,890	68	63	1,119,500	5,369,080

* Data in this table, except for population of counties, are based on 1956 reports.
† Based on results of a special census, April 1957.
‡ Systems are only those with their own sources of water. An additional 195,000 persons in Suffolk are supplied by individual wells.
§ Water supplied wholly by New York City, primarily from upstate sources.
‖ From a report by the New York City Dept. of Water Supply, Gas, and Electricity (9).
¶ Data for Nassau may be incomplete.
** This includes the US Air Force base at Mitchell Field, estimated population, 8,500.
†† This includes 21 wells or stations at twelve plants of the Suffolk County Water Authority, shown as separate installations and supplying about 181,500 persons.

Other Suppliers

Several private companies have also supplied water to consumers in Brook-

TABLE 2

Ground Water Withdrawal in Long Island—1948–56

Year	Average Ground Water Withdrawal—*mgd*					
	Public Supply	Industrial Use			Agricultural Use	Total of All Uses
		Wasted	Recharged	Total		
Kings County						
1948	0	21.9	7.1	29.0		29.0
1949	0	21.1	9.9	31.0		31.0
1950	0	19.7	8.7	28.4		28.4
1951	0	16.1	11.8	27.9		27.9
1952	0	12.3	12.8	25.1		25.1
1953	0	12.0	12.8	24.8		24.8
1954	0	11.7	13.2	24.9		24.9
1955	0	11.7	12.8	24.5		24.5
1956	0	11.1	12.8	23.9		23.9
Averages	0	15.3	11.3	26.6		26.6
Queens County *						
1948	44.0	9.0	5.0	14.0		58.0
1949	54.0	7.3	4.7	12.0		66.0
1950	51.2	9.3	5.2	14.5		65.7
1951	38.2	8.9	6.0	14.9		53.1
1952	42.2	7.3	6.8	14.1		56.3
1953	45.2	7.2	6.8	14.0		59.2
1954	51.7	7.7	7.6	15.3		67.0
1955	47.5	8.1	8.1	16.2		63.7
1956	46.0	7.6	8.4	16.0		62.0
Averages	46.7	8.0	6.5	14.6		61.3
Nassau County *						
1948	83.0	1.6	5.4	7.0	5.0	95.0
1949	102.0	1.5	5.5	7.0	3.0	112.0
1950	100.0	2.7	6.1	8.8	0.9	109.7
1951	69.5	5.3	6.7	12.0	0.9	82.4
1952	76.5	5.1	8.8	13.9	0.6	90.0
1953	100.0	6.2	11.5	17.7	0.3	118.0
1954	140.7	5.3	12.2	17.5	0.5	158.7
1955	106.2	6.2	13.9	20.1	0.5	126.8
1956	98.0	5.8	16.2	22.0	0.3	120.3
Averages	97.2	4.4	9.6	14.0	1.3	112.5

* The public supply averages for Queens and Nassau include withdrawals by New York City.

TABLE 2—*Ground Water Withdrawal in Long Island—1948–56 (contd.)*

Year	Average Ground Water Withdrawal—*mgd*					
	Public Supply	Industrial Use			Agricultural Use	Total of All Uses
		Wasted	Recharged	Total		
	Suffolk County †					
1948	32.0	3.5	8.5	12.0	9.0	53.0
1949	34.0	4.0	7.0	11.0	17.0	62.0
1950	24.3	5.1	7.3	12.4	5.6	42.3
1951	24.5	5.0	8.4	13.4	9.4	47.3
1952	25.6	5.5	10.5	16.0	16.0	57.6
1953	27.8	5.6	12.0	17.6	16.0	61.4
1954	27.5	6.6	13.4	20.0	16.9	64.4
1955	27.1	7.4	14.5	21.9	17.6	66.6
1956	28.9	4.0	13.4	17.4	8.2	54.5
Averages	28.0	5.2	10.6	15.7	12.9	56.6
Averages for Long Island	43.0	8.2	9.5	17.7	3.6	64.3

† The public supply averages for Suffolk include withdrawals for private domestic use, which are estimated at 8–10 mgd.

lyn and Queens. These companies used ground water almost entirely. After 1898 the city gradually acquired most of these companies, and now only two still operate independently within the boroughs of Kings and Queens: the Jamaica Water Supply Co. and the New York Water Service Corp. During the same period numerous publicly owned systems and several private water companies started operation in Nassau and Suffolk counties. They developed ground water only and sold and distributed it locally. These systems have grown as the population has increased. Table 1 gives the number of public water-supply systems in operation in the four counties of Long Island in 1956 and the estimated populations served by them.

Withdrawal

The withdrawal of ground water from Kings, Queens, and Nassau counties by New York City from 1904 to 1918, when the Catskill system was completed, averaged 110–150 mgd, more than half of it from Nassau. Figure 4 shows ground water withdrawals from 1918 to 1956. These data show some significant points:

1. When the Catskill system was completed a temporary curtailment of New York City withdrawals followed. In 1920 New York began to take ground water from Long Island again, but, in general, at a decreasing rate. Withdrawals by the city were heaviest in Kings County until 1917, heaviest in Queens and Nassau from about 1923 to 1943, and concentrated almost entirely in Nassau from 1943 to 1954. In contrast, withdrawals by private companies and water districts increased steadily in all three counties after 1918. In Kings County the withdrawals by these agencies stabilized in the late

1930's and were stopped completely in 1947 because of sea-water contamination. In Queens the increase was small but steady, continuing through 1956. In Nassau it was rapid, especially from 1950 to 1956, paralleling the rapid growth of population.

2. Since 1950, except for 1954, there has been very little draft on the ground water of Long Island by New York City. This is a complete reversal of the trend during the early years, and should be correlated with the construction of the Catskill and Delaware facilities upstate. It is in accord with the policy stated several times in a 1942 decision of the New York State Water Power and Control Commission: "The remaining unused and unappropriated ground water resources of Long Island must be reserved for and dedicated to the needs of the people of Nassau and Suffolk counties" (*10*).

Figure 4 does not cover Suffolk County, nor does it show ground water withdrawal for industrial and agricultural use. Table 2 shows withdrawal of ground water for public supply and industrial and agricultural use in the four Long Island counties for the years 1948–56. In the island as a whole the withdrawals for public supply are by far the largest, although industrial withdrawals are large in Kings and Queens. Withdrawals for agricultural use, mostly irrigation, in Suffolk County are appreciable. There was no significant agricultural use of water in Kings and Queens. The total withdrawals in 1956 were at an average rate of about 260 mgd. The average of Nassau and Suffolk was about 175 mgd, and from Nassau alone about 120 mgd.

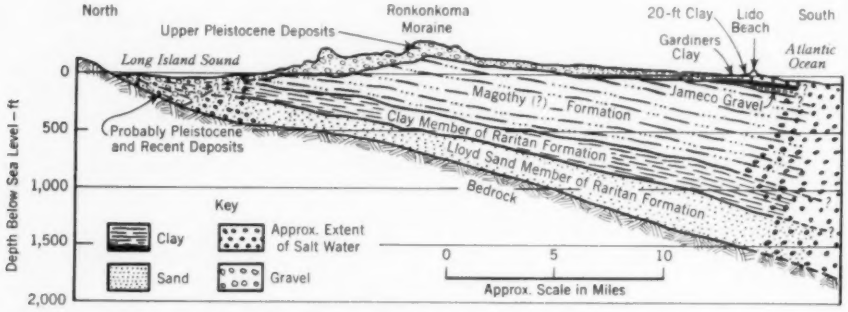

Fig. 5. Geologic Units of Central Nassau

The water-bearing geologic formation of central Nassau County is shown. The question marks are used when the exact boundary is not known.

Status of Knowledge

Considering the demand for water and the need for understanding its occurrence, present knowledge is in many ways deficient. There is, however, a good deal known, in general, about the ground water of Long Island and the geologic conditions that control it.

The water-bearing materials of Long Island comprise unconsolidated deposits of Cretaceous and Pleistocene

age, having an aggregate thickness that ranges from less than 100 ft in the northwest to more than 1,500 ft beneath the central part of the south shore. These materials underlie a total land area of about 1,370 sq mi. There are four chief water-producing units: at the top the upper Pleistocene deposits, next the Jameco gravel, then the Magothy (?) formation, and at the bottom the Lloyd sand member of the Raritan formation (Fig. 5). However, little is known about the transmissibility of these formations and knowledge of the Pleistocene stratigraphy is woefully generalized.

In general, the depth to the water table in most of Long Island and the approximate natural range in fluctuation are known. Little information on the static heads of the artesian water near the shores is available and there is, essentially, no information on the heads in the adjoining salt-water bodies.

It is known that salt water lies adjacent to and beneath the fresh water on all sides of Long Island and that along most of the periphery of the island salt water is at or off the shore. In three general areas salt water occurs inland: in Kings County, in southwestern Nassau County, and in parts of the north fork in eastern Suffolk County. It has not been determined where the landward edge of the salt water is in most places nor how fast or in what direction it is moving, although it is certainly moving very slowly

The average replenishment of the ground water reservoirs is some proportion, probably something less than half, of the average annual precipitation, which is about 45 in. The exact proportion is not known, however, and there are no reliable figures for specific areas of small relative size.

Most of the natural discharge from the ground water reservoirs is into the lower reaches of the streams. However, systematic stream-flow measurements, which date from 1936 in Nassau County and 1942 in Suffolk County, are made at sites some distance upstream from tidewater. It is not known what proportion of the natural discharge escapes unmeasured to the sea downstream from the gaging stations, nor has any practical way of estimating it directly been developed.

Available Supply

Several estimates were made in earlier years of the amount of water available for use, mainly in selected parts of Long Island. These estimates are either too general to be applied safely to specific areas or they are based on erroneous assumptions, expressed or tacitly assumed. It is important to have accurate estimates of the amount of water that can be withdrawn under desired conditions of movement or stabilization of the salt-water zone of diffusion because in some sizable areas the use of water is probably approaching the amount available. For example, in Nassau County the population is now almost 1,000,000. The Nassau land area is 274 sq mi. If the average rate of replenishment of ground water is on the order of 0.6 mgd/sq mi—a conservative though reasonable figure according to available data—the average rate at which water is added to the ground water reservoirs will be about 165 mgd. Current withdrawals are at the rate of about 120 mgd. At present a large but unknown part of the withdrawal is returned to the

ground, but a large amount (24 mgd, which it is planned to increase to about 44 mgd) is discharged into the ocean through sewers. In the near future the net withdrawal may be from one-half to three-quarters of the replenishment, depending on how much used water is returned to the ground. A similar situation exists in Queens County on the west and in parts of Suffolk County on the east.

Some of the earlier estimates of the amount of water available should be examined. Interestingly, most of the estimates of Long Island's water have been made by those whose aim was to take it away.

Although there were earlier reports, the first comprehensive work was that of the Burr-Hering-Freeman commission for an additional water supply for the city of New York (*11*). For this report, Spear (who was the author of Appendix vii of the report) conducted a short but thorough investigation of the water resources of the southern part of Nassau County and of Suffolk County as far east as Patchogue. It was an excellent job. The report contains considerable information and it considers all the major elements of the hydrologic cycle that investigators are working with today. Measurements or estimates were made of rainfall, evapotranspiration, "percolation" (rainfall minus evapotranspiration and direct runoff), stream flow (including a separation of flood flow and ground water runoff—now sometimes called base flow), and underground movement of water. The first work by the USGS (*12*) on Long Island was started in conjunction with the investigation of the Burr-Hering-Freeman commission. Briefly, within the catchment area of the Ridgewood System (Fig. 3) evapotranspiration and direct runoff were subtracted from the rainfall to obtain a figure for replenishment of ground water. Flood flow of the streams was estimated directly and subtracted from the total stream flow to obtain the proportion of the stream flow that was ground water discharge. The difference between the replenishment ground water and the ground water part of the stream flow was then taken as the: "total volume of the underflow toward the sea (*11*)." The commission proposed that this total volume, plus the naturally or artificially filtered stream flow should be developed to provide a ground water supply.

This important and excellent work had two unfortunate elements: it was assumed that all but 5–10 per cent of the underflow as computed could be developed safely (*11*) and the total amount of water was converted into a figure for millions of gallons per day per square mile.

The first assumption was understandable because there was little real knowledge at the time of the subsurface deposits of Long Island and of the movement of the ground water in them. It seems to have been based on the misconceptions that the underflow is independent of stream flow, and that all but about 10 per cent of the underflow could be intercepted without causing sea-water encroachment. However, in 1900 Ward (*8*) had pointed out that from 1883 to 1899 increased draft from wells had caused a substantial diminution of the normal flow of the streams tapped by the Brooklyn Water Works. Also, as early as 1895 it was known that salty water was even then being pumped from some of the early well installations of the city of Brooklyn (*13*).

In the light of subsequent developments the second unfortunate element may be called a tactical error. The error lies in the fact that the method may lead to the false idea that the safe yield of a part of a coastal region such as Long Island is simply the infiltration from precipitation on the total land area considered. For one thing, total land area is not the same as the effective ground water contributing area, a fact which Spear recognized (*11*). For another, all the infiltration cannot always be relied on, even within the contributing area.

In 1908 Spear, then Division Engineer for the Board of Water Supply, city of New York, completed another report (*13*) in which an estimate of the ground water available in Suffolk County was the main objective. Spear extended the earlier data through 1907 and added information on Suffolk County. He used the actual production of the Ridgewood System for the years 1897–1907 as the chief basis for estimating yield. He added surface-water overflow but no additional amount for ground water underflow. He obtained an average yield of 800,000 gpd/sq mi. Spear stated that the minimum yield might be increased to 900,000 gpd/sq mi by further ground water development, but that during a long period of deficient rainfall it might be 15–20 per cent less. He apparently assumed that this draft would be "safe," although he recognized that some fresh-water storage was being replaced by salt water moving in from the sea.

Spear applied the figure of 800,000 gpd/sq mi to the effective drainage areas under consideration in Suffolk County. In this report, however, Spear took advantage of the knowledge at hand on the diminution of stream flow and chloride contamination of the ground water in the old Brooklyn system. Also, he made use of the knowledge he obtained during a visit to certain European cities, notably Amsterdam, where he acquired the then-current understanding of the relationships between the sea and adjoining bodies of fresh ground water. On the basis of this he proposed, for example, to limit the depths of wells to 150–200 ft, to place them 1½ mi from shore in a zone where the water table was 20 ft above sea level, and to limit the drawdown to 15 ft. In effect, Spear planned to allow escape of an appreciable part of the ground water underflow to the sea so as to prevent sea-water contamination of the supply. He thus substantially modified the earlier assumption that all but 5–10 per cent of the underflow could be developed safely. Spear continued the practice of estimating yield on a per-square-mile basis.

In 1934 Wiggin (*14*) made an estimate of the water available in Kings and Queens counties. He used the period 1903–32, for which he obtained records and made estimates of the total pumpage. Wiggin estimated the volume of water removed in the net decline of the water table for the same period. Subtracting this amount from the total pumpage, and making certain other assumptions, he obtained the "inflow," which in effect was the replenishment of ground water. This amount Wiggin converted to a figure of 1 mgd/sq mi of so-called pervious area. Again it was apparently assumed that all this water could be withdrawn for use even though Wiggin himself recognized that in the later years of the period considered some of the fresh-water storage was being replaced by salt water.

In 1937 Suter (*15*) reported estimates of water available for the whole of Long Island. He took the figure of half the average annual rainfall, 1 mgd/sq mi, subtracted current (1937) discharge by sewers, and made further reductions, for reasons not fully explained. He derived the following figures for "safe present (1937) development":

County	Area *sq mi*	Total Yield *mgd*
Kings	71	0
Queens	108	30
Nassau	274	130
Suffolk	920	460

Suter also continued the practice of estimating yield on a per-square-mile basis. Evidently, however, he was using the total land area, which is not everywhere coincident with the effective ground water contributing area.

Suter's estimates were conservative enough for planning purposes at the time, considering the comparatively small net withdrawals during the 1930's in Nassau and Suffolk counties. More accurately based estimates are needed now, however, especially for conditions where the withdrawals approach the replenishment.

Recently (1957) Wiggin completed a report on the water resources of Suffolk County in which he estimated the amount of water available (*16*). He divided the county into several subareas, subtracted certain marginal lands from the total area considered, and applied conservative figures for the safe ground water yield per square mile, using different values for the different subareas. The basis for the selection of the yield values was not given.

Whereas Spear, in 1908 (*13*), and Wiggin, in 1934 (*14*), estimated the total amount of water available and converted that to a per-square-mile figure, investigators are now taking an opposite approach. Modern investigators take arbitrarily adjusted figures for water available per square mile and multiply by an assumed number of square miles to obtain a total. Admittedly, this method has some basis in experience and if capably and conservatively done it can give estimates that are safe for preliminary planning. Wiggin, in 1957 (*16*), did recognize the desirability of withdrawing only part of the natural replenishment so as to leave a certain amount of natural discharge to help prevent sea-water encroachment. Actually, preventing ultimate sea-water encroachment involves much more than simply allowing some discharge to escape. At least, however, modern investigators seem to be rediscovering what Spear recognized 50 years ago: all of the replenishment cannot "safely" be pumped. These and other problems should be given serious and careful consideration if the water resources of Long Island are to be completely and "safely" developed.

Problems

Many problems, political, legal, and technical, will have to be solved before the water resources of Nassau and Suffolk counties can be fully used to satisfy the needs of their people. This article has discussed the five most important technical problems:

1. Close estimation of the amount of replenishment in different parts of the counties

2. Direct determination of the proportion of this replenishment that can

be used without contamination of the supply by sea water

3. Determination of the desired conditions under which the selected amount can be withdrawn

4. Apportionment of the withdrawals by geologic formations and by geographical areas

5. Production of the net artificial discharge from the ground water system.

Modern data on evapotranspiration are fairly accurate, and, therefore, the residual from precipitation that can pass more or less permanently beneath the land surface also can be determined fairly accurately. However, where the water goes when it passes beneath the reach of plant roots and just how much of it reaches productive ground water reservoirs is not so easily determined, especially in the north-shore areas of Long Island which have a complex geology. Furthermore, the replenishment probably varies a good deal from place to place, which would mean that overall estimates by counties are not applicable locally.

Direct determination of the amount of the replenishment that can practicably be withdrawn and of the applicable conditions also is essential. These problems involve a number of subsidiary factors and relationships now mostly not known or understood, such as: exact location of the fresh-salt interfaces beneath the shores; expectable positions of the interfaces under differently spaced and increased drafts on the fresh-water bodies; length of time it may take for an interface to shift from one position to another; and desirability or practicability of adjusting withdrawals so as to maintain the interfaces in about their present positions.

The optimum distribution of withdrawals by formations and by geographic areas also is a problem. The upper Pleistocene deposits contain the most permeable zones in most parts of Long Island and are the most readily replenished. Yet they are the deposits most readily subject to contamination from the land surface, especially by septic tanks and cesspools. Thus, there has been pressure to withdraw relatively more and more water from the deeper artesian aquifers. Withdrawal from the deeper aquifers, especially near the shore, has a greater and more immediate effect on landward movement of adjoining salt-water bodies. This conflict needs to be resolved. The more water that can be taken in areas of natural discharge the more water there will be in the system elsewhere to weigh against the encroachment of salt water.

The increasing practice of conducting used water of all kinds directly into the ocean through pipelines and sewage-disposal plants continually increases the net withdrawal from the ground water reservoirs. Means of returning much or all of this water to the ground without causing contamination, like the return of air-conditioning water, would materially reduce the net artificial withdrawal and thereby, in effect, increase the amount of water available.

Acknowledgment

The author acknowledges the assistance of John A. Saccareccia, Assistant Hydraulic Engineer, Westbury office of the New York State Water Power and Control Commission, who prepared Table 1 of this article.

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Discussion

W. Fred Welsch

Sr. Hydr. Engr., Nassau County Dept. of Public Works, Mineola, N.Y.

To supplement this article the writer believes it would be of interest to include a discussion of the conservation measures adopted and being perpetuated in Nassau and Suffolk counties over a period of many years. Since 1932 Nassau County has been engaged in the investigation of ground water resources on Long Island and since 1936 in the investigation of surface water resources, in cooperation with USGS and the New York State Water Power and Control Commission.

Long Island

Long Island is the largest island on the Atlantic Coast of the United States. It is entirely surrounded by tidal salt waters: the Atlantic Ocean on the south and the Long Island Sound on

the north. The island itself is about 15 mi in width and extends eastward from Manhattan for about 125 mi (Fig. 1). A part of New York State, Long Island is divided into four counties (Fig. 3). The two westernmost—Kings (Brooklyn) and Queens—are boroughs of New York City and have a combined population of about 4,500,000. East of them lies the major part of Long Island: Nassau County, next to Queens, with 1,200,000 people; and the much larger Suffolk County, with 600,000 residents, forming the eastern segment of the island.

As the population of Long Island increased more and more streets were paved, homes, schools, churches, and industrial buildings in great numbers were erected, and sanitary sewers and storm drains were installed. The runoff of storm waters from pavements and roofs greatly increased. The family cistern which stored the runoff of soft rain water from the roof has gone the way of the artesian well. Instead of collecting in cisterns or naturally percolating into the ground rain water was carried away to tidewaters in vast quantities by storm sewers. The pumping levels of ground water wells were decreasing. The need, therefore, was to devise a system of drainage that would restore rainfall to the soil and maintain the ground water at stable levels.

Conservation Program

In anticipation of continued population increase the Nassau County Board of Supervisors authorized in 1936 the development of a long-range master drainage and water conservation program, which was prepared for the then-existing Nassau County Sanitation Commission (now the Board of Supervisors) under the writer's direction.

This plan provided for the construction of artificial storm-water recharge and impounding basins of 1 acre or more in size in areas where feasible as a conservation measure to replenish ground water storage. It was expected that this would save millions of gallons of rain water which otherwise would be lost to the tidal salt waters.

Recharge basins have several purposes:

1. To replenish the ground water supply by returning to the ground the storm-water runoff from rainfall. The runoff otherwise would be carried off to streams and from there to tidal salt waters
2. To provide drainage outlets without construction of long conduits to streams or tidewaters
3. To reduce the size of conduits required for storm-water drainage by impounding waters during peak flows
4. To discharge waste water from air-conditioning systems and uncontaminated water used for industrial processing at industrial plants.

Under the long-range drainage and conservation program 405 recharge basins have been developed and have been operated successfully in Nassau. In Suffolk County more than 400 recharge basins have been developed.

Large-diameter precast diffusion pipe wells with flared openings have also been successful in draining small tributary areas, such as parking fields, street intersections connected with corner catch basins, and shopping centers. They have also been installed in several artificial recharge basins to augment seepage capacity.

In Nassau County approximately 40 mgd and in Suffolk County approximately 10 mgd of storm-water runoff are estimated to annually replenish the ground water storage at the present

time (May 1958). Future development may ultimately increase these figures to 50 mgd in Suffolk and 70 mgd in Nassau.

Current efforts to conserve ground water supplies also include recharge basins of 1 acre or more in size, storm-water diffusion wells, diffusion wells for cooling and air-conditioning water, industrial waste treatment and water reuse, and enlightened study and control by governmental agencies.

It should be emphasized that the cooperative survey program with the USGS, Water Resources Division, Ground and Surface Water branches, has provided invaluable assistance to Nassau and Suffolk counties in making an authoritative appraisal of the factors of water requirements, water resources, future development for domestic, industrial, commercial, agricultural, air-conditioning, and air cooling uses, and the requirements for intelligent, long-range planning. These solutions are basic to the continued growth, health, and welfare of the public and to assure an adequate water supply for the future.

An extensive literature supplementing this discussion is available (*1–13*).

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Liquid Alum Incorporated in Revised B403 Standard

AWWA B403—Standard for Aluminum Sulfate has been revised to include liquid alum, in accordance with action taken by the Board of Directors in 1958. The standard, which formerly covered only lump and ground aluminum sulfate and was designated B403–54, has been redesignated B403–58. The sections principally affected now read:

Sec. 1A—Scope

This standard covers aluminum sulfate, either purified or unpurified and in lump, ground, or liquid form, for use in the treatment of municipal and industrial water supplies. The standard is intended for use in connection with Part B (Sampling, Inspection, Packing, and Marking) and Part C (Testing Methods) of this document.

* * *

Sec. 8A—Clarity

Liquid aluminum sulfate shall be reasonably clear. It shall be of such clarity as to permit the reading of flow-measuring devices without difficulty.

Sec. 9A—Content of Alumina

9A.1. *Lump or ground* aluminum sulfate shall contain not less than 17 per cent available water-soluble alumina (Al_2O_3).

9A.2. *Liquid* aluminum sulfate shall contain not less than 8.0 per cent available water-soluble alumina (Al_2O_3), except by agreement between the manufacturer and the purchaser.

[Former Sec. 9A and 10A have been renumbered 10A and 11A respectively.]

Sec. 12A—Insoluble and Suspended Material

12A.1. In unpurified *lump or ground* aluminum sulfate, the insoluble matter shall not exceed 10 per cent.

12A.2. In purified *lump or ground* aluminum sulfate, the insoluble matter shall not exceed 0.5 per cent.

12A.3. In *liquid* aluminum sulfate, the suspended matter shall not exceed 0.2 per cent.

Sec. 13A—Data to Be Furnished by Manufacturer

The manufacturer shall, when requested, furnish the purchaser a sworn affidavit stating that the material, if ordered to conform with the requirements of this standard, does in fact do so in all details.

* * *

Sec. 2B—Sampling

2B.1. Samples shall be taken at the point of destination.

2B.2—*Lump or ground aluminum sulfate:*

[Former Sec. 2B.2 through 2B.6 have been renumbered 2B.2.1 through 2B.2.5, respectively.]

2B.3—*Liquid aluminum sulfate:*

2B.3.1. Five equal portions shall be taken at five equally spaced time intervals during the unloading of the tank truck or railroad car. The total sample shall equal 2 qt.

2B.3.2. The gross sample (2 qt) shall be thoroughly mixed and three 1-pt samples retained. They shall be sealed in airtight, moistureproof glass containers. Each sample container shall be labeled to identify it, and the label shall be signed by the sampler.

Sec. 3B—Packing and Shipping

[Former Sec. 3B.1 and 3B.2 have been combined as 3B.1.]

3B.2. *Liquid* aluminum sulfate may be shipped in tank trucks containing 2,000–4,000 gal or railroad tank cars containing approximately 10,000 gal. The tanks shall be rubber lined or made of stainless steel or any other suitable material which will not be attacked by the acidity of the liquid. If smaller quantities are purchased, an agreement between the manufacturer and the purchaser shall be made as to the size and type of container.

Sec. 4B—Marking

4B.1. Each shipment of *lump or ground* material shall carry with it some means of identification. Each package shall have marked legibly thereon the net weight of the contents, the name of the manufacturer, and the brand name, if any. The package may be marked "Purified" or "Unpurified."

4B.2. Shipments of *liquid* aluminum sulfate shall comply with the Interstate Commerce Commission regulations for marking.

* * *

Sec. 2C—Sampling

* * *

2C.3. The sample of *liquid* aluminum sulfate for analysis shall be pipetted in exact volume into a tared weighing bottle and weighed (1 ml of liquid aluminum sulfate, 8.0 per cent Al_2O_3, weighs approximately 1.316 g). As liquid aluminum sulfate is close to a 50 per cent solution of dry aluminum sulfate, the weight of the liquid sample used should be about twice the weight shown in the procedure for dry aluminum sulfate.

The approximate amount of Al_2O_3 present can be obtained by measuring the specific gravity with an accurate hydrometer at a known temperature. Hydrometers of different makes may exhibit slight variations. The manufacturer will furnish a table showing the percentage of Al_2O_3 for different specific-gravity readings.

[Former Sec. 2C.3 has been renumbered 2C.4.]

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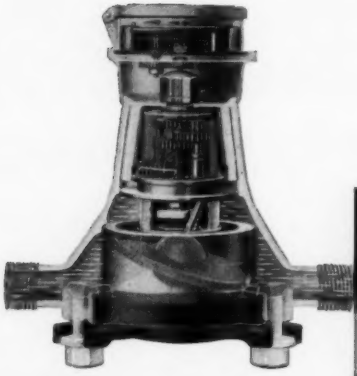

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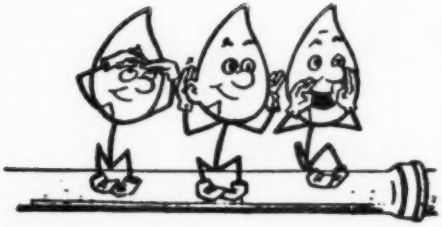

Percolation and Runoff

The shape of things to come seems to be strictly blobular—algaic, that is—for it is upon those tasteful and odorific unicellular nuisances that science seems to be pinning its hopes for human survival these days. Considering war too potentially catastrophic and such "menaces" as safe water, penicillin, and DDT to have undone the more natural "correctives," such present prophets as Aldous Huxley suggest that, "so far as the masses of mankind are concerned, the coming time will not be the Space Age; it will be the Age of Overpopulation." And that appears to be where the algae come in, bearing not only food, but water and air as well.

That algae are a source of food—fat as well as protein—has long been known, as has their fantastic productivity. When it is considered that *Chlorella*, for instance, can produce more than fifteen times as much food per acre as soybeans and that there are approximately four times as many acres of water as there are of land, the potentialities for plenty should be patent. And if an *Aphanizomenon* pattie sounds somewhat less attractive right now than a porterhouse steak, never doubt that our food technologists will find a way to make it at least as delectable and certainly more certainly chewable, whether rare or well done.

The hydroalgic cycle, on the other hand, was introduced only last summer, when, on the occasion of the international symposium on saline water conversion, Gilbert B. Levin of Resources Research, Inc., suggested that the ability of algae to take up large quantities of salt when the sun shines on them be employed in the production of fresh water from the sea. To complete the cycle, it was Gil's thought that this desalinization process, which is reversed in the absence of sunlight, could be established as the first stage in an algal food plant.

Finally, it was at the first international symposium on submarine and space medicine that the role of algae in producing air was featured. There it was T. A. Gaucher of General Dynamics Corp. who pointed out that, in addition to providing nutritive food in a space ship or submarine, the algae could help replenish the oxygen supply and remove carbon dioxide waste through the process of photosynthesis. As a step toward assuring enough of both for an indefinitely long trip, he announced the development of a new strain of algae which reproduces 125

(*Continued on page 36 P&R*)

(*Continued from page 35 P&R*)

times faster than the normal variety—1,000 times per day, that is, compared to only 8. The more heirs, of course, the more air, as well as edibles. As for the sunlight, even under the sea that can be provided by a new General Electric lamp which produces a light many times more potent than the natural stuff.

What this all means, of course, is that the simplest of living things offers the most complicated a simple solution to a most complicated problem. Not only will algae provide food for new billions of humans here on Earth, but they promise to make possible the search for new living space in space—or even under the sea. Wonderful—and inevitable—as this may prove algae to be, though, we are somehow less enthusiastic about being around when the first scum is first served.

The shape of things to come in the more immediate future, meanwhile, will apparently continue to be skeletonized largely in steel, with the production estimate for 1959 at 108,000,000 tons, 25 per cent above the 1958 figure. All of which, considering the steel industry's past record as an index of construction activities, would seem to bode well for "Do It Now!"

AWWA's admiralty received strong reinforcement last December when, from the "Headquarters of the Honorable Order of Kentucky Colonels at Anchorage, Ky.," issued this pronouncement:

In the name and by the authority of the Commonwealth of Kentucky, Albert Benjamin Chandler, Governor of the Commonwealth of Kentucky, To All to Whom These Presents Shall Come, Greeting; Know Ye That Honorable Ed Cleary, Cincinnati, Ohio, having been duly appointed, is hereby commissioned, Admiral of the Ohio River.

Lest there be any question of Governor Chandler's authority as a "Kentucky" governor extending to the "Ohio" River, we can cite the Northwest Territory Act of 1787, which declared that the boundary of Kentucky would be the *northern* bank of the Ohio River for the more than 700 miles of its 1,000-mile length to its junction with the Mississippi. This, of course, makes Ed's admiralty at least 70 per cent incontestable, and, as any naval presumptions of three of the other four states involved would probably be exercised in the Atlantic and as Ed's position is executive director of the sanitation commission in which they all are associated, it is doubtful that any contest would be joined.

Senior to Ed among AWWA's admirals are Louisville's purification superintendent Bill Williams, commissioned several years ago as an Admiral of the Kentucky River, and AWWA secretary Harry Jordan, who, in 1955, was appointed Admiral of the Nebraska Navy. Ed claims to rank Bill in that the Kentucky is merely a tributary of the Ohio; Harry claims that no one can be ranker than he. As far as we're concerned they're all brass and we salute them!

J. R. Townsend, special assistant, Office of Assistant Secretary of Defense (Research & Engineering), has been elected president of ASA, succeeding H. Thomas Hallowell Jr. The new vice-president is Frank H. Roby, of Federal Pacific Electric Corp., Newark, N.J. Mr. Townsend, an outstanding authority on standards work, is a past president of ASTM.

(*Continued on page 38 P&R*)

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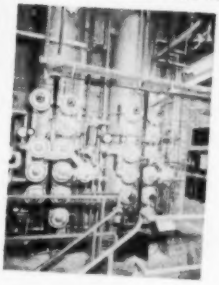

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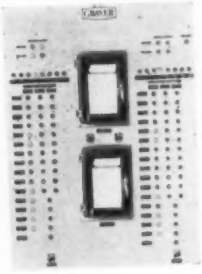

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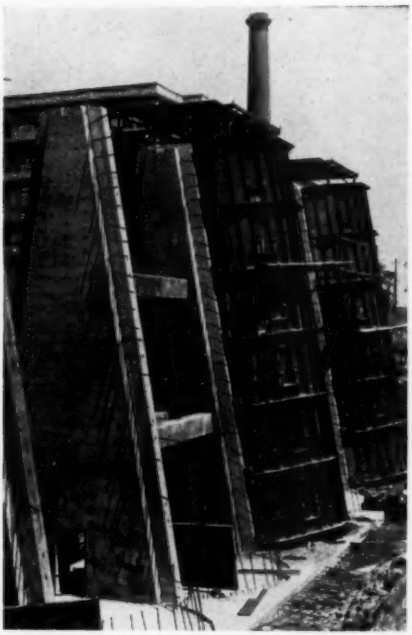
(Continued from page 36 P&R)

The unique distribution reservoir shown in the photos below is in process of construction at the Chain of Rocks Plant, St. Louis City Water Dept. The walls of the 10-mil gal basin, which will be underground, are composed of sloping cylindrical concrete shells. This patented design, originated by E. E. Easterday, chief engineer of the St. Louis Water Dept., is stabilized with five struts. Struts are omitted from intervening cells so that the arch can flex under expansion or contraction of the structure. The roof, a concrete flat slab with tar and gravel upper surface, is supported by 225 columns and is free floating—unconnected with the walls—so as to ride over the top of the cells during expansion and contraction. Drainage



is intended to provide a virtually foolproof barrier against penetration of ground water into the drinking-water supply.

Each wall of the square basin, 281 ft long and 30 ft high, is formed by fifteen of the hollow concrete cells, interconnected so that inspectors can examine the interior for the entire length of the wall. Every other cell is provided for the roof and at the ground level.

Approximately 11,500 cu yd of concrete will be used in the basin, reinforced with 928 tons of multirib round reinforcing bars and other steel reinforcement. General contractor is G. L. Tarlton Contracting Co., St. Louis. The steel is a product of Laclede Steel Co.

(Continued on page 40 P&R)

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(*Continued from page 38 P&R*)

Fresh fish stories, not too long ago thought impossible, are being spawned these days in the records of pollution control agencies. Unlike the old tales, these usually feature not the ones that got away, but the ones that came back.

Characteristic of these more credible reports is the one released last September by the Ohio River Valley Water Sanitation Commission, reporting that caviar is now being processed from Ohio River fish eggs. Just 10 years ago any self-respecting fish would have said a tough "whoa" to roe in an Ohio that was being loaded with the untreated sewage of more than 99 per cent of the riparian population and the untreated wastes of more than 75 per cent of its industrial plants. Now, however, with 92 per cent of the sewage and 74 per cent of the industrial wastes being treated, the fish are back —131 species of them, according to a recent survey, including not only catfish, drum, and shad, but large-mouthed and spotted bass. It was from a catch of more than a ton of paddlefish in a week that one commercial fisherman obtained enough roe to process as caviar and to inspire an ORSANCO challenge to Khrushchev.

From Vermont, on the other hand, a really fresh story features the ones that have to be thrown back. And it was not the elimination of pollution, but its introduction that was involved in making the fish worthy of a story. The whole project, in the words of Jim MacMartin, biologist of the State Fish and Game Service, who supervises it,

(*Continued on page 42 P&R*)

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ERIE, PA.

(*Continued from page 40 P&R*)

hinges on the fact that, in waters of very low calcium content, fish are faced with a large-size job just to stay ahead of the osmotic flow of water into their tissues. When they are expending great amounts of energy on the bilge pumps (kidneys), they evidently don't have much left for the growth process. The Cortland Experimental Hatchery has found, by using radioactive tracers, that a trout in 5-ppm Ca water has three times the metabolic rate of the same trout in 50-ppm water. The stream involved in the project is the Roaring Branch of the Battenkill River in the Sunderland-Arlington area of Vermont. The branch flows from the limestoneless mountains to the east of the main-stem valley, its waters having a calcium hardness of not more than 4 ppm, with pH consistently from 4.0 to 5.0. The idea was that we might be able to ease the kidney load of trout in this soft water by placing limestone rubble beds in the stream to beef up its calcium content. What we have been using to date is waste (fist to football size) from a crushing plant in Wallingford. As yet, the project is in the pilot stage and we haven't enough results to warrant expansion of the idea to other waters, but I believe the theory is sound. At any rate we have noted that random shocker catches of trout from hard waters have a much higher proportion of legal fish than do those in very soft water. We plan to continue these experiments, perhaps using different materials and methods for increasing water calcium.

We don't know that it was fishful thinking, but it might just as well have been, that inspired the clean-streams-conscious Pennsylvania Dept. of Health to express official regret when one of the state's industries went out of business and, thus, stopped discharging its wastes into Slippery Rock Creek. The industry involved was a limestone mine and washery, the waste from which had neutralized the acidity of coal mine drainage that also flowed into the creek. If the coal miners can't be forced to, perhaps the Izaak Walton League will want to take over the defunct operation—that is, if all of Slippery Rock's fish weren't pickled long ago.

All of which is to suggest that even we, "the compleat nonfisherman," are happy to note the success of pollution control agencies in bringing back not only the fish, but his tale!

Everett M. Jones has resigned as vice-president and general manager of Simplex Valve & Meter Co., Lancaster, Pa. His successor as general manager is J. M. Hultz, his former assistant.

A competitive examination for appointment as sanitary engineer officers in the USPHS Regular Corps will be held in various places Apr. 21–24. Appointments providing opportunities for career service, including research, will be made in the grades of assistant and senior assistant, equivalent to US Navy ranks of lieutenant (j.g.) and lieutenant, respectively. (Active duty as a USPHS officer fulfills the obligations of selective service.)

Applicants for assistant sanitary engineer officer must be United States citizens and graduates of recognized engineering colleges or universities, with at least 3 years of postgraduate training and experience. Applicants for senior assistant must have an additional 3 years.

Further details and application forms can be obtained from the Surgeon General, US Public Health Service (P), Washington 25, D.C. Completed forms must be received no later than Mar. 6.

(*Continued on page 44 P&R*)

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4362

(*Continued from page 42 P&R*)

Two truck bodies "job planned" for water line maintenance service are illustrated below. They were manufactured by Reading Body Works, Inc., of Reading, Pa., for the Indianapolis (Ind.) Water Co. Rankin-Wood & Co., of Indianapolis, Reading Body's distributor, specially adapted the bodies for the utility. The steel bodies are mounted on dual-wheel, 2½-ton Dodge chassis. Both vehicles have roller bearing–mounted telescopic roofs

and seats inside the body for work crews. A generator and pump are mounted in compartments in each body. The generator supplies power for lighting night operations and for small electrical tools. The pump is used to dewater trenches. A heavy-duty air compressor, installed inside the body, supplies air for pavement breakers and other pneumatic equipment. Watertight compartments with divided shelves, bins, and trays provide storage for parts and equipment. Pipe and mechanic's vises are mounted on the rear platform. The truck at left mounts a heavy-duty arm derrick on its rear platform.

Wallace & Tiernan Inc. announces the election of Robert M. Jackson as president, succeeding F. G. Merckel who has retired. Mr. Merckel will, however, remain on the board of directors and will act as an adviser on operations. Mr. Jackson has been with the Belleville, N.J., firm, which manufactures chemicals and equipment, since 1930 and has held the offices of executive vice-president and treasurer.

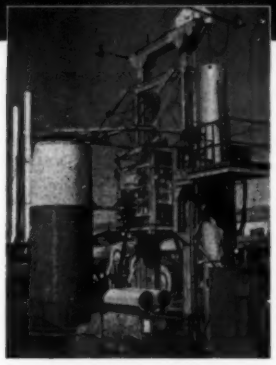
Thomas T. Quigley, director of the Equipment Div., has been named a vice-president, as has Charles H. Rybolt, head of the Chemical Div. Harald A. Gilman succeeds Mr. Jackson as treasurer of the company.

(*Continued on page 46 P&R*)

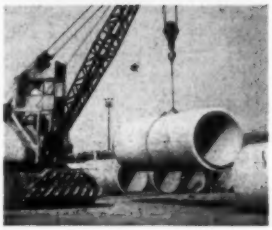
PRESTRESSED
CONCRETE CYLINDER PIPE
(Embedded Cylinder Type)

with Rubber Gasket Joint

All of the good qualities and characteristics desired by water works engineers for permanent water supply and transmission lines are embodied in this prestressed pipe of advanced design: great strength, sustained high carrying capacity, trouble-free service, and unusually long life. Prestressed pipe of this type can be designed more accurately, predictably and economically for most all conditions of internal pressure and external loads than any other type of high quality concrete pressure pipe. It is the finest quality pipe available in medium and large diameters for pressures generally ranging from 100 psi upward. American is currently undertaking the manufacture of this pipe designed for pressures ranging from 275 to 550 ft. of head for a portion of the U.S. Bureau of Reclamation Project being constructed for the Ventura River Municipal Water District. This Ventura River Project will serve 32 square miles of mountainous country with water for irrigation, municipal and industrial use in main and coastal reaches of Ventura County, California. When planning *your* future water "growth lines," look to American's quality pipe line products, extensive production facilities and half century of experience.



Prestressing machine wraps high tensile steel wire under carefully measured tension around pipe core.



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CONCRETE PIPE FOR MAIN WATER SUPPLY LINES, STORM AND SANITARY SEWERS, SUBAQUEOUS LINES

(Continued from page 44 P&R)

Edward E. Alt, of Chicago Bridge & Iron Co., Chicago, was installed as president of WSWMA during the group's New York meeting in December. The new president of the manufacturers association has long been active in AWWA affairs. He is a past chairman of the Illinois Section and also served as national director from the section. In 1956 he received the Fuller Award on its nomination.

Water samples and stream flow data from some of the 65 major rivers of the world are beginning to arrive at the US Geological Survey as part of a worldwide effort to learn how much water flows into the oceans and how much of the land these rivers carry off as dissolved solids. Data on riverborne dissolved chemical substances are becoming increasingly important in newer technical concepts, such as total water budget and the relationship of runoff to precipitation. The best available estimates of the total amount of dissolved solids carried by the rivers, which dump about 18 bil gal of water a minute into the oceans, range from 280,000 to 450,000 tons an hour. The figures are believed to be on the conservative side.

The work of collecting new and meaningful data has been assigned to a "Committee on World-Wide Runoff of Dissolved Solids," appointed from members of the International Assn. of Hydrology of the International Union of Geodesy & Geophysics. Principal coordinator is Walton H. Durum, chemist in the USGS Water Resources Div. The sampling program is set up for a year, but it is hoped to continue beyond this time in order to improve the reliability of the data. Water samples are to be taken at least four times annually near the mouth of each river. Turbid or muddy samples are filtered at the time of collection, with the aid of a unique but simple filter unit devised for this program. Only dissolved solids are included in the study. The collection of data on solids carried in suspension is another problem entirely, one that will be considerably more difficult to coordinate when the time comes.

In each kit used by the samplers there are two 2-liter polyethylene bottles, one of which the collector fills with filtered or natural run-of-the-river water. For the second sample, the water will be filtered and nitric acid added to make certain that elements present only in small traces will not be lost (the minor elements, mostly metals, are changed into more stable nitrates). The first sample is analyzed for about twenty chemical substances that can be determined readily by conventional laboratory methods, and the second sample is analyzed by a spectrograph for trace elements. The 65 chosen rivers provide up to 75 per cent of the total runoff to the oceans.

Cyrus R. Bird has retired as vice-president of The Pitometer Assocs., after 40 years with the hydraulic-survey firm. His successor as vice-president and western manager in charge of the Chicago office is W. D. Hudson, principal engineer, who has headed the Atlanta, Ga., office since 1950.

(Continued on page 48 P&R)

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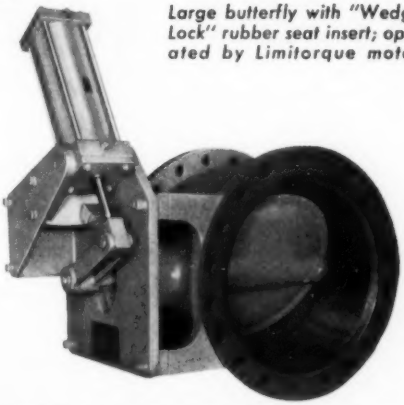
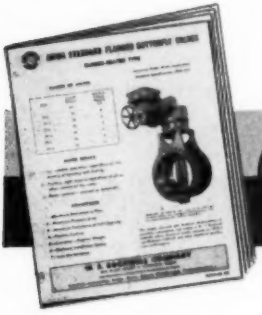
As proved in many water service installations throughout the country, Rockwell standard butterfly valves meet and exceed AWWA specifications for design, construction and dependable service. "Wedge-Lock" rubber seat or all rubber lining, stainless steel edged disc, stainless steel shaft, combined with manual or mechanical operator, assures performance plus under all conditions. Let Rockwell recommend the best for your next valve installation. Bulletin 581 tells why.

Large butterfly with "Wedge-Lock" rubber seat insert; operated by Limitorque motor.



Butterfly valve with spool rubber liner; hydraulically operated.



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(*Continued from page 46 P&R*)

Gone to the devil is one of the wells on Chalmer Lovdahl's farm in Monmouth, Ill., and after 36 years of more than satisfactory service. What's more, no one—including experts from the State Water Survey, the State Health Dept., the University of Illinois, or even the soft-water service from Madison, Wis.—can tell Chalmer what the devil is wrong with it. Having provided clear, cold water for household use—"far colder and better for drinking than water from a nearby well, 125 ft deep"—all these years, the well suddenly began to warm up last August, becoming progressively hotter until it leveled off in November at 101°F. Now that it is acting like one of hell's wells, Chalmer is impaled on the horns of, well, a dilemma. He'd guess he was perched on an incipient volcano were it not for the fact that the 125-ft well nearby hasn't changed temperature a bit. He's tempted to hook the other well up to his hot-water system and make the best of it, but . . . . And who ever heard of a well—even a 36-year-old one—burning itself out? *WELL*—what do you think?

Gone to the dogs, at least to the tune of $80,000, is the San Jose Water Works. The dogs are Mac and George, a sort of Irish terrier and a mostly cocker spaniel, whose master, a childless widower, left his estate to them with instructions to the executor to turn it all into cash and purchase water works stock. The 1,500 shares owned by the canine capitalists will

(*Continued on page 50 P&R*)

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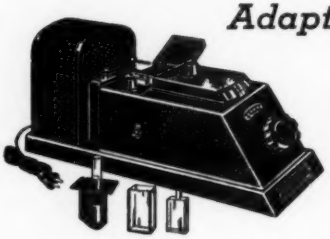

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(Continued from page 48 P&R)

earn more than $3,000 per year, which should be enough to give them "the best of care." Meanwhile, Ralph Elsman, president of the utility, is no doubt considering the proper placement of hydrants during stockholders meetings.

Lock Joint Pipe Co., East Orange, N.J., manufacturer of reinforced concrete pipe, has named Philip R. Hirsh chairman of the board. He was formerly executive vice-president. C. Mack Albertson, western district manager, has been appointed manager of pressure pipe sales.

Charles J. Alfke has retired as executive vice-president of Hackensack Water Co., Weehawken, N.J., a post he had held since 1941. Mr. Alfke joined the company in 1924.

Cooperstown, N.Y., whose citizens appreciate the good things in life, have just added honor to honor in augmenting a stone marker with a bronze plaque to mark the "site of the Old Town Pump which supplied our village with much of the water used for domestic purposes for 80 years, and with that used to fight several fires, including the conflagration of 1862." And while you're in town to see these monuments to faithful water service, you might cross the street to have a look at Doubleday Field or even take a short stroll to visit baseball's Hall of Fame—as long as you're in the vicinity.

Gerard J. Dierker has been elected to succeed the retiring Daniel J. Hennessy as president of Jamaica (N.Y.) Water Supply Co. Mr. Dierker has been the firm's executive vice-president and controller since 1956. The new controller will be Joseph J. Kenney, formerly chief accountant. Mr. Hennessy, who served as president of the company for 13 years, will remain on its board of directors.

Noitagirri—that is, the reverse of irrigation—is what Leon Kluck of Platte County, Neb., practices to assure himself a crop every year on 40 acres of hardpan that is part of his farm. Having harvested only one crop in five in the past because his field became a lake every time a real rain came, Kluck had his well driller sink a 90-ft gravel-packed well at the lowest spot on the field, using 40 ft of perforated casing at the bottom. Near the well he built an $8 \times 7 \times 5$-ft filter box which he packed with gravel. He then connected the filter box with a collecting basin 60 ft long and 16 ft wide, valving the line and putting a grate at its end to prevent entry of stalks and trash. A second line drains the water from the box into the well at a rate that permitted him to drain a 2-ft depth of water in the basin in 90 min. Although the drainage setup cost him $1,000, he will save that on a single crop and at the same time reap an incidental benefit in recharging the aquifer. No dumb Kluck he!

James R. Losee, engineer of the Tarrytown, N.Y., Water & Sewer Dept., who has been identified with the village's progress for the last 50 years, was honored recently as "Man of the Year" by the local chamber of commerce.

(Continued on page 94 P&R)

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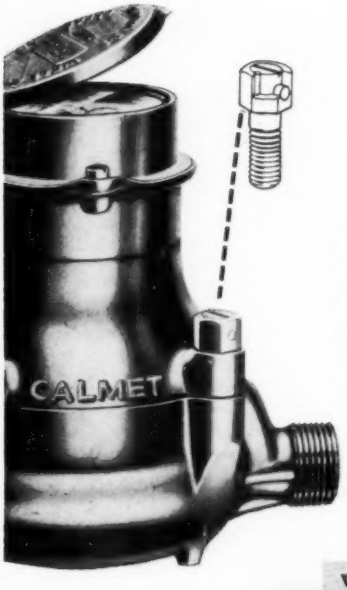

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Senior Sanitary Engineers—Positions available with the New York State Health Dept. Perform public health engineering work either as an engineer in charge of environmental sanitation in a public health district or as assistant to a central office specialist in a major segment of a public health engineering program. Requirements: Bachelor's Degree in engineering, progressively responsible engineering experience with at last two years in sanitary or public health engineering. Eligibility for a New York State professional engineer's license. Salary $7,500–$9,090. Final date for filing for exam, Feb. 15, 1959. For application write Mr. Sylvester J. Bower, Acting Director of Personnel, New York State Health Dept., 84 Holland Ave., Albany, N.Y.

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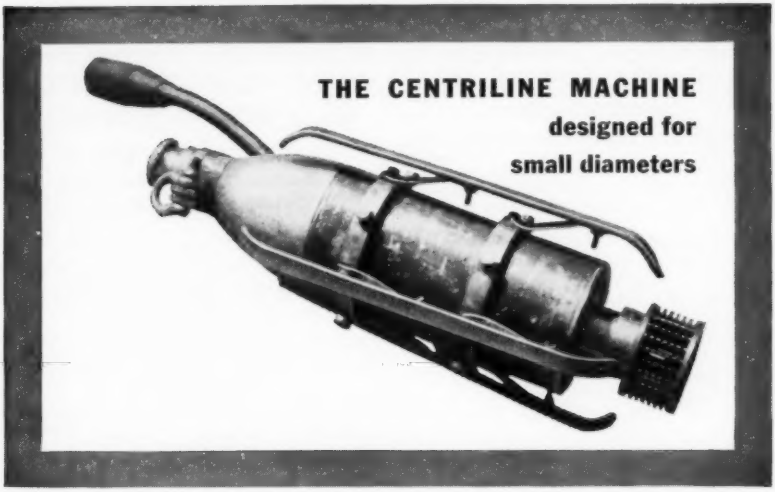

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- Bell Ends

FIG. 571X
- Inside Screw
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- Parallel Seats
- Mechanical Joint Ends

FIG. 561
- Inside Screw
- Non-Rising Stem
- Parallel Seats
- Flanged Ends

FIG. 566
- Outside-Screw-and-Yoke
- Rising Stem
- Parallel Seats
- Flanged Ends

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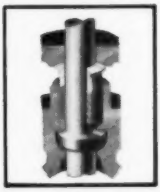

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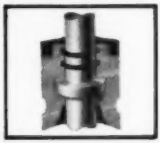

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Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

LABORATORY AND FIELD METHODS

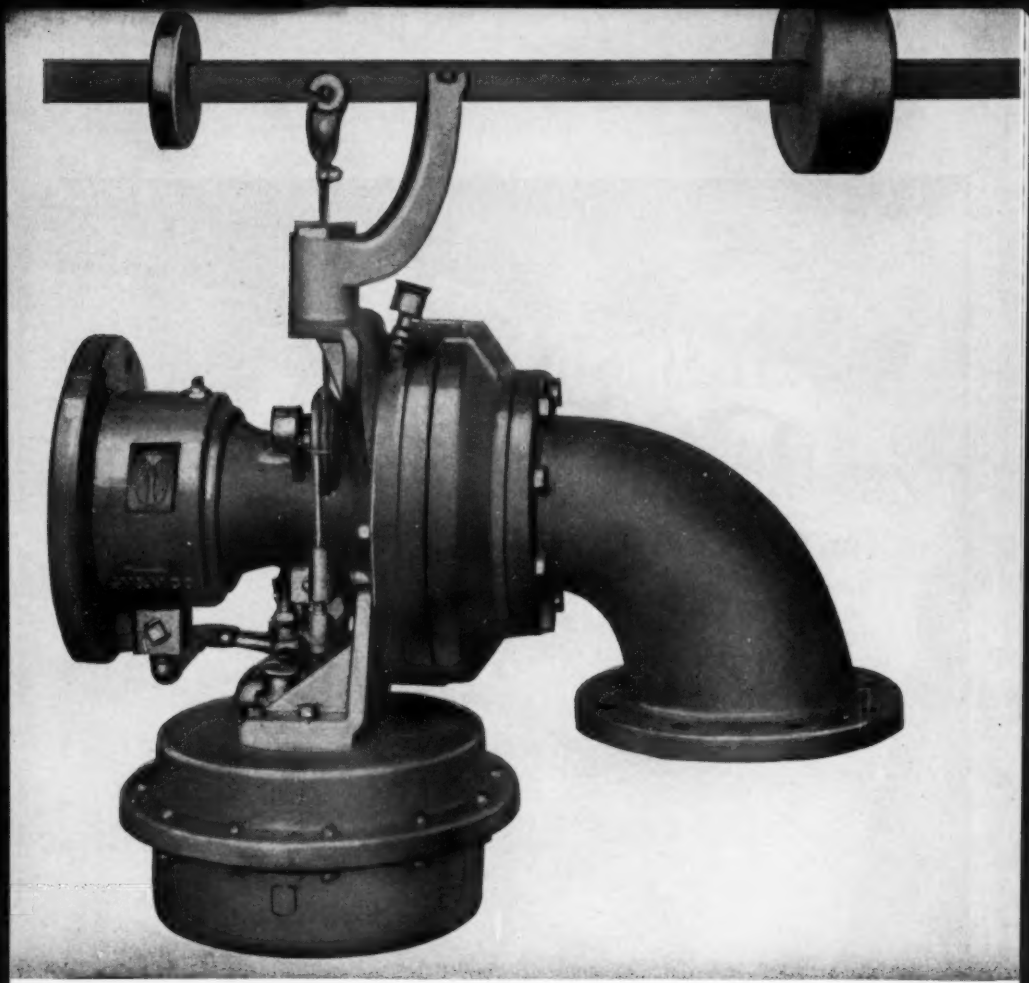
Chromatographic Identification and Determination of Organic Acids in Water. H. F. MUELLER; T. E. LARSON; & W. J. LENNARZ. Anal. Chem., **30**:41 ('58). Butyric, propionic, acetic, pyruvic, formic, lactic, *l*-malic, and citric acids (**I**) have been sepd. and detd. in natural river waters and in sewage effluents from sewage-treatment plants. Samples of water are evapd. to 30% vol., acidified, and **I** removed by continuous ether extraction. Neutralized ethereal soln. is evapd. and **I** adsorbed on silicic acid (**II**). **II** column is used to sep. **I** by elution with varying concns. of BuOH in $CHCl_3$. Eluates are titrated with std. alkali. Technique also provides method for sepn. of anionic syndets from anal. interferences for subsequent detn. —*CA*

The Wet Combustion of Organic Substances With Iodic Acid. II. T. N. KLEINERT. Tappi, **40**:736 ('57). Wet combustion method is described for detn. of nonvolatile org. substances in water in which evapn. residue is heated with soln. of potassium iodate in sulfuric acid. Carbon dioxide evolved is detd. gravimetrically after absorption in tubes contg. soda lime, magnesium perchlorate, and phosphorus pentoxide. Oxygen consumed during combustion is detd. by back-titration of excess iodic acid. Ratio of these two quants., termed combustion factor, is indication of nature and state of oxidation of org. substances present in water; for pure carbohydrates ratio is 1.000, for lignin sulfonic acids it is 0.852. As self-purif. proceeds in a pold. river value of combustion factor approaches that for pure carbohydrates due to presence of algae. Method has been used to det. org. substances present in unpold. river waters and in river water pold. by spent sulfite liquor, and also to estimate deg of self-purif. of pold. waters. App. used is described and illustrated and results of expts. are discussed.—*WPA*

Characterization of Agitation Effects in Shaken Flasks. R. P. RHODES & E. L. GADEN. Ind. Eng. Chem., **49**:1233 ('57). Shaken flasks are frequently used in process studied, but little is known of their performance. Expts. were carried out with rotary and reciprocating flasks to det. their agitation characteristics. To characterize liquid-solid mass transfer, rates of copper ion exchange between dil. solns. of copper sulfate and suspended particles of Amberlite 1R-120 resin was used. Transfer coef. data indicate that mass transfer between liq. and fine suspended solids is poorer in shaken flask than in mechanically stirred system, partly because energy input per unit vol. is mechanically limited in shaker and partly because energy input is distributed throughout whole vol. of liq. instead of being concd. in smaller regions as in stirred device. In case of gas-liq. transfer, however, gas absorption appears to be limiting factor, and shaken flasks can give results comparable to those obtained in mechanically-stirred vessels.—*WPA*

Determination of Low Concentrations of Radioactive Caesium in Water. B. KAHN; D. K. SMITH; & C. P. STRAUB. Anal. Chem., **29**:1210 ('57). 3 methods have been developed for detg. low concns. of radioactive caesium in water. Active caesium, together with mg amts. of caesium chloride carrier, can be pptd. as caesium ammonium phosphomolybdate, copptd. with sodium potassium cobaltinitrite, or concd. on cation-exchange resin and then purified by established radiochem. procedures. All 3 methods give satisfactory recovery and decontamn. from long-lived fission products. Methods have been used to det. radioactive caesium in river water in concns. of 10^{-4}–10^{-8} μc/ml.—*WPA*

(*Continued on page 66 P&R*)



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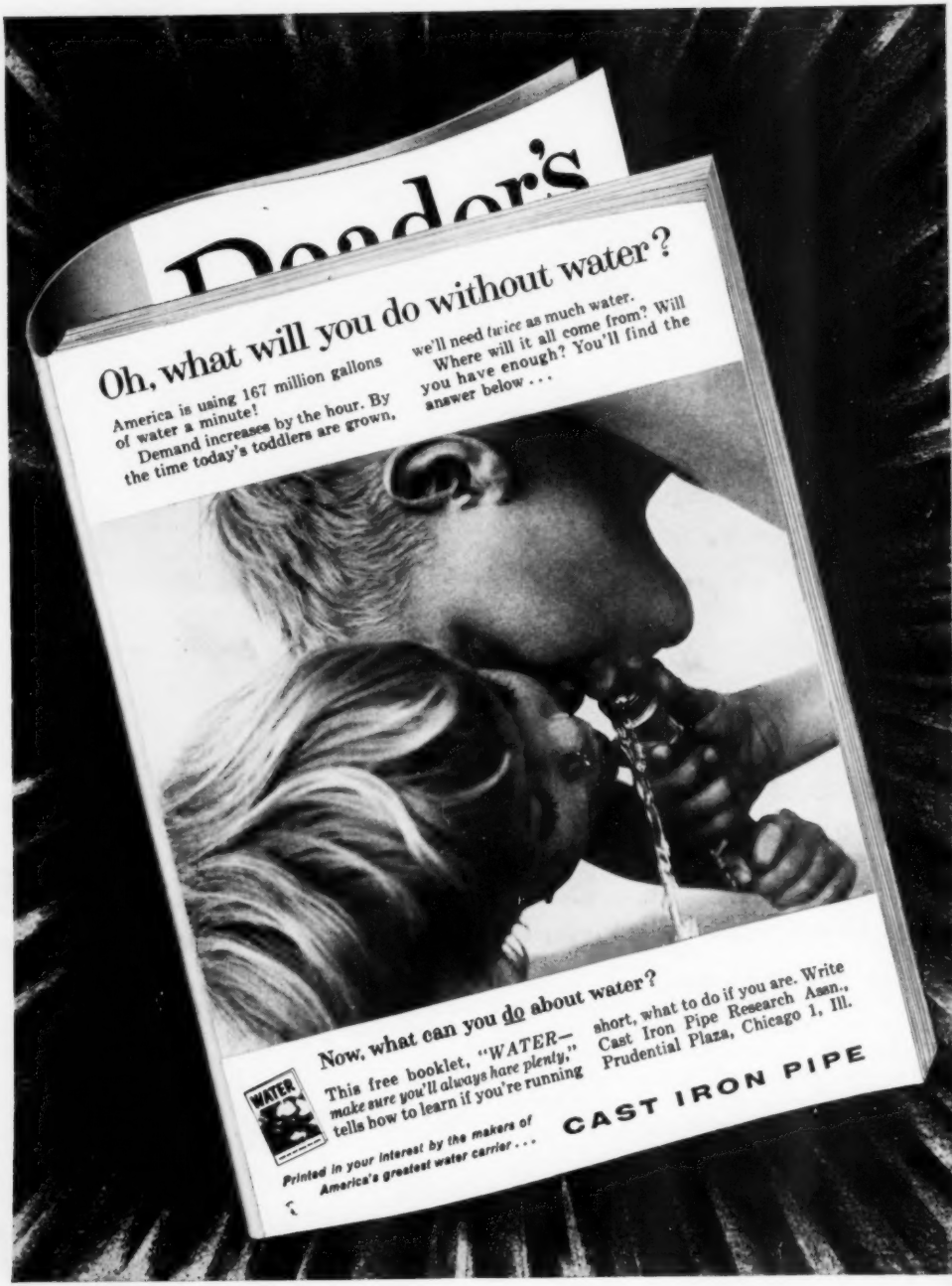
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(*Continued from page 62 P&R*)

Spectrophotometric Determination of Alkyl Benzenesulfonate Detergents in Surface Water and Sewage. J. D. FAIRING & F. R. SHORT. Anal. Chem., **28**:1827 ('56). Alkyl-benzene-sulfonate (ABS) along with some positive interferences is extracted with 0.1% soln. of 1-methylheptylamine in $CHCl_3$ at pH of 7.5. After evapn. of $CHCl_3$ and acid hydrolysis, ABS is extracted with 0.1% soln. of 1-methylheptylamine in hexane at pH of 4.8. After evapn. of hexane, ABS is detd. colorimetrically by methylene blue method.—*CA*

Application of Photometry to Water Analysis. J. W. POLSKY. Am. Ceram. Soc. Bul., **35**:433 ('56). Detn. of sulfates in water using a photoelectric photometer is described. Concns. of as much as 40 ppm sulfate can be detd. with accuracy of ±0.3 ppm. Turbidimeter cell and 415-mμ filter are used. Prepn. of reference soln. contg. sample, sodium chloride, concd. hydrochloric acid, and glycerol; and of test soln. contg. sample, sodium chloride, concd. hydrochloric acid, and barium chloride, are described. Photometer is calibrated with known amts. of sulfate.—*WPA*

Murexide as a Reagent for the Colorimetric Determination of Calcium. G. G. KARANOVICH. Trudy Vsesoyuy. Nauch.-Issledovatel Inst. Khim. Reactiv. (USSR), **21**:48 ('56). In detn. of calcium using murexide orange-pink color is obtained which reaches max. intensity after 1 min. Reaction is sensitive to 20 μg calcium in 5 ml of soln. at pH 6 and 1 μg calcium in 5 ml at pH 12–13. Stability of color is greatest when 0.2 ml normal sodium hydroxide per 5 ml is added. 400 μg of magnesium will not interfere in presence of 1 ml *N* sodium hydroxide. Interference is caused by not less than 12 μg iron, 1–3 μg cupric, zinc, cadmium, nickel, chromic, and manganic ions and not more than 25 μg of mercuric ions. If sodium fluoride is added 50 μg iron may be screened but presence of magnesium will interfere with reaction. When calcium: magnesium ratio is 1:200 ferric ions and heavy metals may be complexed with diethylcarbamate and extracted with isobutyl alcohol. Aq. soln. of calcium and magnesium is detd. with murexide at pH 12. Aluminium, lead, barium, arsenic, platinum, and sodium do not interfere when present in ratios of calcium to metal of 1:50, 1:50, 1:25, 1:12.5, 1:250, and 1:1,000 resp.—*WPA*

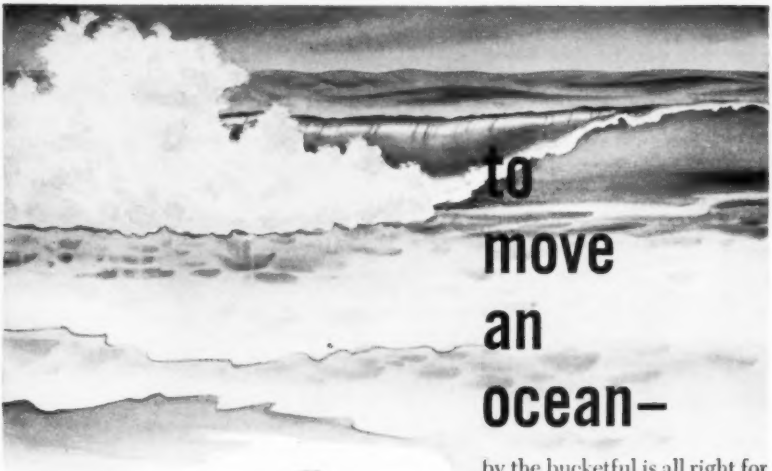
Photometric Determination of Calcium by Precipitation of Its Naphthylhydroxamate. A. M. AMIN. Chemist Analyst, **46**:2:31 ('57). Calcium is detd. by pptn. from boiling ammoniacal soln., using sodium naphthylhydroxamate. Ppt. is washed by centrifuging and dissolved with excess disodium, ethylenediaminetetraacetate (EDTA) in presence of ammoniacal buffer. Calcium forms complex with EDTA and naphthalhydroxamate ions, equiv. to the calcium ions added, are released and give yellow to brick-red color to soln. Extinction is measured with spectrophotometer at 410 mμ or with filter photometer using blue filter.—*WPA*

Stepwise EDTA Titration of Calcium and Magnesium with C.I. 202 and C.I. 203 as Indicators. P. F. LOTT & K. L. CHENG. Chemist Analyst, **46**:2:30 ('57). To det. calcium and magnesium in same sample pH value is adjusted to 13 when magnesium is then present as insol. hydroxide. Calcium is titrated with disodium ethylenediaminetetraacetate using either sodium salt of 1-(2-hydroxy-1-naphthylazo)-2-naphthol-4-sulfonic acid (C.I. 202) or its zinc complex as indicator. pH value is then adjusted to 10 and magnesium is titrated with EDTA using Eriochrome black T (C.I. 203) as indicator. —*WPA*

Volumetric Determination of Calcium and Magnesium Content [of Water] by Means of the Disodium Salt of Ethylenediaminetetraacetic Acid. E. KINT. Ind. Chim. Belge (Brussels), **21**:1021 ('56). Volumetric detn. of calcium and magnesium in water using disodium salt of ethylenediaminetetraacetic acid (EDTA) with Eriochrome black T and murexide as indicators, is reviewed. It is proposed to replace ammonia-ammonium chloride buffer soln. and Eriochrome black T indicator with combined buffer-indicator soln., contg. sodium carbonate, Eriochrome black T, hydroxylamine hydrochloride, magnesium sulfate, and EDTA. Prepn. of reagent is described. For each 50 ml of sample to be titrated 1 ml of reagent is used.—*WPA*

Quantitative Determination of Traces of Carbon Dioxide in Water. P. P. JENNINGS & E. M. OSBORN. Analyst (Br.), **82**:671 ('57). Procedure and special app. for detn. of 0.01–0.10 ppm CO_2 in boiler feedwater are described. CO_2 is aspirated

(*Continued on page 68 P&R*)



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WRITE FOR ILLUSTRATED BULLETIN NO. B-148

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(*Continued from page 66 P&R*)

from acidified sample, absorbed in NaOH soln., and titrated from pH 8.3 to 5.0 with std. acid. Very careful attention to details is essential. Error is 0.002 ppm, provided sample taken contains <1 mg CO_2.—*CA*

Cerimetry Applied to Analysis of Water. H. Lecoq. Chim. anal, (Paris), **39**:232 ('57). Procedure is given for detn. of oxygen demand of raw water with ceric sulfate. Sample is refluxed with concd. sulfuric acid and acidic soln. of ceric sulfate for 20 min, cooled, and back-titrated with ferrous sulfate soln. to ferroin end-point. —*WPA*

Neutral Red as a Test Reagent in the Chlorination of Water. S. Elliott. J. Roy. Army Med. Corps (London), **103**:2:74 ('57). Test for presence of free chlorine in water, which can be used in field under army service conditions, is based on fact that neutral red in acid soln. becomes yellow or is bleached by effective concns. of free chlorine, but is unaffected by chlorine-ammonia. As different batches of this dye vary considerably, it is necessary to use specific brand of dye. Detailed procedure for test is given. No interference is caused by ferric iron, manganese, and nitrite.—*WPA*

The Isolation of Bacteriophage from Water by the Chloroform Method. P. Monnet; H. Le Tellier; & A. Drevon. Rev. Hyg. et Med. Sociale (Paris), **6**:2:221 ('58). Since '53 authors have applied chloroform method for examn. of drinking water and river water samples for presence of bacteriophages of faecal microorganisms. Altogether 444 drinking water samples and 43 river samples were examd. Sensitive organism used was *Shigella paradysenteriae* and it was possible to make comparison with filtration method. Advantage of chloroform method is its rapidity but authors consider it to be essentially presumptive test and, should positive result be obtained, it should be confirmed by filtration method.—*BH*

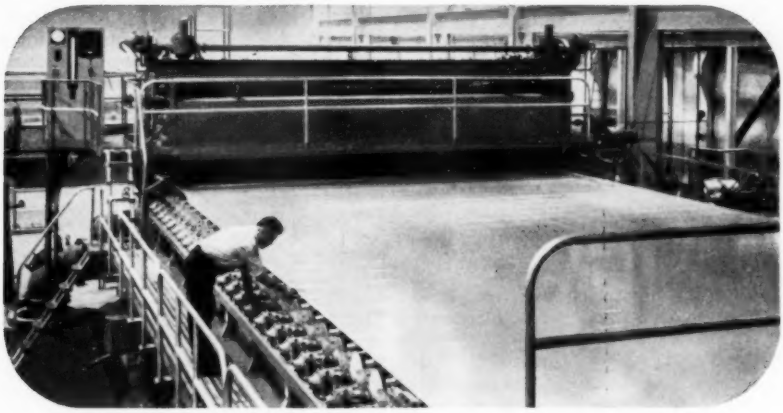
A Modified Method for the Determination of Copper in Boiler Feedwater. D. Parkhouse. Chem. & Ind. (London), 224 ('57). In method for detg. copper in boiler feedwater by extracting with carbon tetrachloride complex formed when sodium diethyldithiocarbamate and buffer are added to water author claims increase in speed and accuracy of method by making single extraction of fixed vol. of water by fixed vol. of carbon tetrachloride. To 500 ml of sample are added 5 ml ammonia-ammonium citrate buffer and 5 ml 0.2% aqueous sodium diethyldithiocarbamate soln. and mixture is extracted for 5 min with 10 ml carbon tetrachloride. Sepd. carbon tetrachloride is centrifuged for 5 min and color of soln. is measured in absorptiometer using violet filter. Detn. takes about 20 min, and 1 ppb copper can be detected. When calibrating absorptiometer author found that copper was not completely removed from water which had been passed through mixed-bed ion-exchange column.—*WPA*

The Use of Oxalyldihydrazide in a New Reaction for the Spectrophotometric Microdetermination of Copper. G. Gran. Anal. Chim. Acta (London, Amsterdam & Houston, Tex.), **14**:150 ('56). New method for spectrophotometric detn. of low concns. of copper is described. To strongly ammoniacal soln. contg. traces of copper are added satd. soln. of oxalyldihydrazide and either formaldehyde or, preferably, acetaldehyde. Intense blue-violet to violet color is obtained, with max. absorbance at wavelength of about 542 mμ. Order of addn. of reagents is important and aldehyde must be added last. Some expts. showed that presence of reasonable amts. of hydrochloric, nitric, and perchloric acids or of sodium sulfate had no effect on absorbancy.—*WPA*

Complexometric Titrations Following Cupferron Separation of Interferences. J. S. Fritz; M. J. Richard; & A. S. Bystroff. Anal. Chem., **29**:577 ('57). Method is described for detn. of divalent metals by titration with EDTA using Eriochrome black T as indicator. Cupferron is added to form complexes with metals of higher valency which otherwise interfere with titration and complexes are extracted by mixture of equal parts benzene and isoamyl alcohol. To avoid extraction of divalent metals pH value is adjusted to 0.3–0.8 with hydrochloric acid. Effect of pH value on amt. of divalent metal extracted is shown by graph. Method has been tested with samples contg. known quants. of divalent metals together with 1 or more extractable metals and results are given.—*WPA*

(*Continued on page 70 P&R*)

ION EXCHANGE RESINS condition boiler feed



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It takes a lot of water to run a paper mill, not only as an actual ingredient in paper making, but also for the steam necessary for power generation and for cooling paper machine condensate.

At Minnesota and Ontario Paper Company in International Falls, Minnesota, the feed water to the boiler—rated at 240,000 lbs. per hour, 1290 psig.—must be deionized. This is accomplished by passing the feed water through 1) two parallel beds of AMBERLITE IR-120, a strongly acidic cation exchange resin operating in the hydrogen cycle, 2) a vacuum deaerator, 3) and through two parallel beds of AMBERLITE IRA-400, a strongly basic anion exchange resin. The water has a conductivity of only 1.5 to 3 micromhos, with a silica content of less than .015 ppm. Deionized water requirements vary from 100 to 300 gallons per minute.

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(*Continued from page 68 P&R*)

A New Method for the Microdetermination of the Cupric Ion [in Water] by the Use of an Enzyme. I. YAMAZAKI & K. FUJINAGA. Nippon Kagaku Zasshi (Tokyo), **77**:1213 ('56). Method is described for detn. of low concns. of copper in natural and purified water. It was found that rate of oxidation of reductone with peroxidase increases in presence of more than $10^{-6}M$ copper at pH 7.3, pH value being adjusted by addn. of $0.0025M$ phosphate buffer. Amt. of reductone (approx. $10^{-4}M$) oxidized during given time of reaction is proportional to concn. of copper (less than $10 \times 10^{-6}M$). Similar effect is observed with manganese and cobalt. 0.5 ml of sample soln. is made up to 4 ml with peroxidase soln., 0.5 ml of buffer and reductone soln. ($4 \times 10^{-4}M$ made from glucose and sodium hydroxide) are added and mixture is allowed to stand at 25°C. Reaction is stopped by addn. of 1 ml $3N$ sulfuric acid and the amount of unchanged reductone is detd. iodimetrically.—*WPA*

Photometric Titration of Cyanides. J. BRANDSTETR & S. KOTRLY. Chem. Listy (Prague), **50**:1316 ('56). To det. small quants. of cyanide accurate equivalence point can be obtained by photometric titration. 5 ml of 4% potassium iodide soln. and 5 ml of $6N$ aq. ammonia are added to sample, which is then dild. to 90 ml and titrated using silver nitrate soln. 5 values in all, 2 before and 3 after equivalence point has been reached, are measured using blue filter. End-point is detd. using graphical evaluation. Avg. error is ±0.2%. Chlorides and phosphates do not interfere in this method. —*WPA*

The Quantitative Estimation of a Non-ionic Detergent. J. C. GRIFFITH. Chem. & Ind. (London), 1041 ('57). Ultraviolet spectrophotometric method has been developed for detn. of nonionic detergent Triton X-100. Ultraviolet spectrum of Triton X-100 shows peak at 278 mμ, probably caused by aromatic ring and optical density of this

(*Continued on page 74 P&R*)

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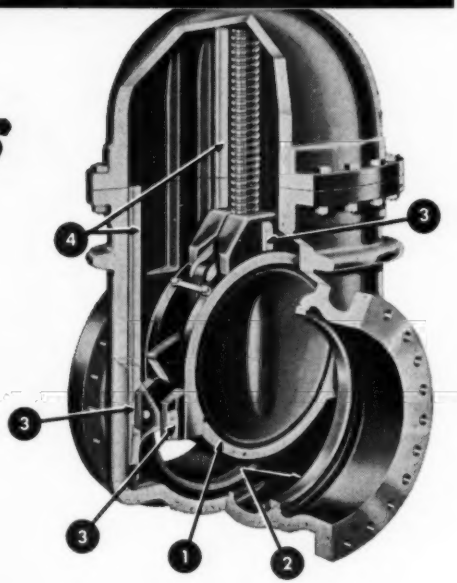

Smith Square Bottom Throttle Construction Valves have all of the time-proven design and construction refinements of standard Smith Gate and Tapping Valves and are recommended for severe service applications such as throttling in a partly open position, daily or frequent operation against high unbalanced pressure, high velocity or installation in a flat position in vertical piping.

The design features consisting of disc shoes and body tracks mechanically lift and hold the disc ring face (1) out of contact with the seat ring face (2) at all points of disc travel with the exception of the fully closed position.

Throttle construction valve discs are provided with three non-ferrous metal shoes (3), precision-machined and jig located. Valve bodies are provided with three non-ferrous metal machined tracks (4). The three disc shoes register with the three body tracks and each shoe is in contact with a track while the valve is unseated and in any partially open position. The bottom section of each track is bevelled to insure that the shoes will not bear on the tracks when the valve is fully closed.

This construction prevents damage to and uneven disc and seat face wear and assures long service life under severe operating conditions.

Single throttle construction is used when the flow is not subject to reversal. Double throttle construction when the flow is subject to reversal.

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(*Continued from page 70 P&R*)

peak, and is reproducible for solns. of same concn., permitting setting up of std. curve. Concns. as low as 0.005% wt. by vol. can be detd. Similar ultraviolet spectrum has been observed in Lissapol NX, which is also believed to contain aromatic ring, and it could presumably be detd. by same method. Other substances absorbing in region of 278 mμ must be absent.—*WPA*

Continuous Removal of DO by Established Ion Exchangers. E. C. POTTER & G. WHITEHEAD. J. Appl. Chem. (London), **7**:629 ('57). Method is described for activating anionic, cationic, or mixed ion-exchange resins for removal of DO from water by pptg. ferrous (or manganous) hydroxide in resin pores. Resin retains its ordinary capac. for ion exchange. Effluents do not become contamd. with Fe, and O conts. of 1 ppb are readily achievable. After Fe^{++} becomes oxidized resultant Fe^{+++} is leached from resin with HCl and new Fe^{++} is deposited to reactivate spent resin. Fe-treated resins are effective in removing from soln. any substance capable of oxidizing $Fe(OH)_2$; removal of peroxides from Et_2O is reported. —*CA*

Determination of DO in Waste Water With a Rotating Platinum Electrode. G. OKAMOTO; T. OKURA; & K. GOTO. Bunseki Kagaku (Tokyo), **5**:408 ('56). Levine's polarographic method for detn. of DO was modified by use of rotating platinum electrode (600 rpm). For regulating soln., satd. potassium chloride contg. 122 g hydrated sodium acetate and 240 ml/l of glacial acetic acid is recommended. Limiting current at −0.60 v is proportional to concn. of DO when this is less than 10 ppm. No interference is caused by presence of nitrous acid. In presence of large amt. of org. substances current is again measured subsequent to removal of DO with nitrogen. Interference of atmospheric oxygen is also small provided that measurement is completed within 20 sec.—*WPA*

Direct-Reading DO Analyzer. Wastes Eng., **28**:193 ('57). Portable DO analyzer is described which consists of rotating platinum electrode with special stable electronic system which automatically translates diffusion current into units of DO concn. It is claimed that instrument dets. concns. of DO ranging from 0 to 10 ppm to within a 5% error. Tests carried out using this instrument are not subject to interference from dissolved iron, calcium, magnesium, sulfides, nitrates, or org. matter. Under certain conditions analyzer can be used for continuous sampling of DO and can be used in conjunction with recorder.—*WPA*

Modified River Sampling for Computing DO Sag. J. D. SIMMONS; N. L. NEMEROW; & T. F. ARMSTRONG. Sew. & Ind. Wastes, **29**:936 ('57). Statistical methods of Churchill and Buckingham were applied in effort to det. DO depletion in stream. Procedure provides quick and relatively simple method of predicting DO deficit of stream below point of poln. It was shown that range and distr. of data collected were more important than no. of samples collected. Only 6 samples were required to produce practical results if each sample is observed under max. or min. conditions of 1 of 3 stream variables. Proper timing of collection of samples would elim. considerable effort and cost in stream study of type proposed by Churchill and Buckingham.—*CA*

Flash Evaporator for Continuous Distillation of Sea Water. Engineer (London), **204**:572 ('57). New design of continuous flash evaporator, which produces distd. water from sea water, is described. Equip. is accommodated in single vessel, brine being pumped through series of heat transfer surfaces where it is gradually heated by condensing vapor produced in series of associated flash chambers. Investigations carried out to prevent scale formation are outlined and procedure for continuous operation of evaporator is described. Flow diagram is given.—*WPA*

Use of a Chelating Agent (EDTA) for Preservation of Coliform Organisms in Water Samples. L. DARDANONI & P. CORDONE. Igiene mod. (It.), **50**:671 ('57). Water samples were treated at moment of sampling with soln. of ethylenediaminetetraacetate (EDTA) in order to investigate effect of chelating agents on coliform cont. of water during storage of samples. It is claimed that this substance prevents coliform organisms from dying during interval between collection of sample and commencement of lab. examn. Soln. of EDTA is made up as follows: ethylenediaminetetra-

(*Continued on page 76 P&R*)

BRINE FILTRATION

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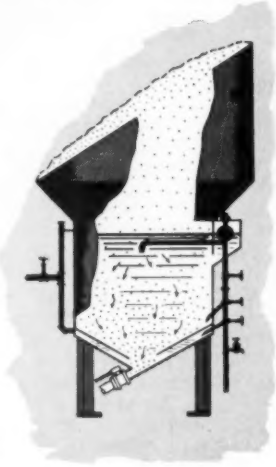

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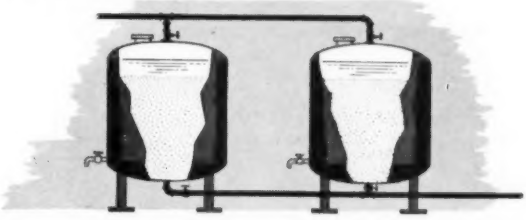

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(*Continued from page 74 P&R*)

acetate (tetrasodium salt), 10 g; hydrochloric acid (N1), 10 ml; water, 80 ml; pH, 6.5. During prepn. of water sample bottles for use, each receives 2 ml of this soln. before it is sterilized at 121°C for 15 min. 116 waters were examd. and 100 (86%) of chelated samples gave coliform counts higher than or equal to untreated samples, 58% giving significantly higher counts. In 7 samples coliform index was between 10 and 45 in chelated samples but was 0 in untreated portions. Results are briefly discussed and possibility of systematic use of chelation in sampling waters for bact. anal. is suggested.—*BH*

Microdetermination of Fluorine in Water. T. AKIYAMA ET AL. Kyoto Yakka Saigaku Gakuho (Jap.), **4**:23 ('56). Water contg. small amt. of F is titrated with $Th(NO_3)_4$ soln. with Na alizarinsulfonate as indicator under pH 3.2–3.4. Interfering ions such as SO_4^{--}, PO_4^{---}, CO_3^{--}, or HCO_3^- are elimd. by prior treatment with $BaCl_2$, and Cl^- is removed with $Na_2S_2O_3$ soln.—*CA*

Colorimetric Determination of Iron by $\alpha\alpha'$-Dipyridyl. M. G. CABANAC. Anal. Chem. Acta (London, Amsterdam, Houston, Tex.), **17**:348 ('57). Iron in alloy of platinum was detd. colorimetrically after removal of platinum by pptn. with zinc dust. After addn. of $\alpha\alpha'$-dipyridyl usual color failed to develop, although reaction proceeded normally when platinum was removed by pptn. with sodium hypophosphite. Series of detns. were made using solns. contg. known quant. of iron and increasing quants. of zinc. It was found that color only developed normally if ratio of zinc to iron was less than 25.—*WPA*

Testing the Penman Formula by Means of Lysimeters. G. F. MAKKINK. J. Inst. Water Engrs. (London), **11**:277 ('57). Trials were conducted at Wageningen, Neth., in '53 to compare observed values for evapotranspiration, obtained from lysimeters, with values calcd. by Penman's formula. On avg., calcd. values were 13% lower than observed values and possible reasons for this were examd. Signif. of ht of grass on and around lysimeters is considered and corrections based on resulting roughness of field and extra radiation area are calcd. Description of lysimeters is given and results of trials are shown.—*WPA*

The Colorimetric Determination of Manganese in Water. G. GAD & W. HOPPE. Gesundh.-Ing. (Munich), **78**:85 ('57). After critical examn. of various methods for colorimetric detn. of manganese in water authors recommend Marschall's method using ammonium persulfate and describe modification in which heat of reaction is utilized and sepn. of silver chloride is prevented by addn. of mercury nitrate. 50 ml of sample are treated in succession with slight excess of mercury nitrate soln. (1 ml/200 mg chloride/l), 1 ml of 1% silver nitrate soln., 5 ml of mixture of 90-ml concd. sulfuric acid and 10 ml of 65% nitric acid, 6 tablets of sodium hydroxide, and approx. 1 g ammonium persulfate. After 10 min color formed by manganese is detd. colorimetrically in usual way, using potassium permanganate soln. for prepn. of std. If iron is present in amts. greater than 3 mg/l sample is treated before measurement of color with 1 ml phosphoric acid.—*WPA*

The Titration of Bivalent Metals With the Disodium Salt of Ethylenediaminetetraacetic Acid. J. HASLAM; D. C. M. SQUIRREL; & M. HESKINS. Analyst (Br.), **82**:117 ('57). In Schwarzenbach method for detn. of bivalent metals with disodium salt of ethylenediaminetetraacetic acid (EDTA) it is often difficult to detect end-point when metal detd. forms highly-colored complex. Alternative form of titration is now proposed in which bivalent metal, such as copper or zinc, is titrated with a standardized soln. of EDTA until further addn. of titrant produces no further change in pH value of soln. and no indicators are required.—*WPA*

The Colorimetric Determination of Nitrates in Water. E. HLUCHAN & J. MAYER. Chem. Zvesti (Czech.), **10**:387 ('56). Colorimetric method for detn. of small amts. of nitrates in water by Na salicylate and trichloroacetic acid is described. Max. absorption of yellow-colored solns. is at 410 mμ. Direct dependence of color intensity on amt. of nitrates is high as 70 μg NO_3^- in 50 ml. Interfering effect of cations can be elimd. by filtration thru ion exchanger. Of anions NO_3^- increases color intensity; it can be elimd. by addn. of small amt. of Na azide in ion exchanger before filtration. I^- and Br^- decrease yellow-color intensity in amts. >25 μg.—*CA*

(*Continued on page 78 P&R*)

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(*Continued from page 76 P&R*)

Determination of Nitrate in Fresh Water. Concentration of Samples by an Ion-Exchange Procedure. A. D. WESTLAND & R. R. LANGFORD. Anal. Chem., **28**:1996 ('56). Detn. of NO_3^- in 0.1-ppm range can be accomplished by concn. on Cl-form ion-exchange resin. After elution with 1% NaCl soln. NO_3 is detd. colorimetrically by strychnidine method. Interference by NO_2^- is prevented by addn. of sulfanilic acid.—*CA*

Determination of Nitrates in Boiler Water by 2,4-Xylenol. J. S. SWAIN. Chem. & Ind. (London), 479 ('57). 5-ml sample is treated with 85% by wt. H_2SO_4 and 1 ml of 2,4-xylenol soln. Temp. is maintained at 35°F for 30 min. Mixt. is transferred to 250-ml distn. flask with 100 ml distd. water and 40 ml is distd. into 10 ml of 2*N* NaOH. Transmittancy of soln. is measured by using Ilford filter #601 and cells 1–40 cm depending on max. concn., 300 to 30 ppm, resp., of $NaNO_3$. Readings are made against reagent blank. Std. curve is prepd. from std. solns. of $NaNO_3$.—*CA*

Method for the Determination of Nitrate by Titration With Ferrous Sulfate. F. KREJCI & L. KACETL. Chem. & Ind. (London), 598 ('57). Simple, inexpensive carbon electrode has been developed for use with platinum electrode in potentiometric detn. of nitrates by titration with ferrous sulfate. With this electrode system, changes in potential are practically independent of ferrous-ion concn., no amplification is needed with ordinary potentiometers, and results are not affected by oxygen absorbed during titration. Results from detn. of nitrogen in nitrocellulose by this method are compared with those obtained by Lunge's method and by using stainless steel electrode.—*WPA*

Rapid Determination of Nitrates in Boiler Water. R. L. BABKIN & K. P. EPEIKINA. Energetik (Moscow), **4**:8:13 ('56). Nitrates in boiler H_2O were detd. by titrating very acid, hot sample with indigo carmine (**I**) soln. which was standardized against $NaNO_3$. For nitrate detn., 10 ml are taken, 10 ml concd. H_2SO_4 are added, soln. is mixed, and titrated immediately with **I** soln. until yellow color turns dirty green. Titer of **I** soln. should be such that 10-ml H_2O sample requires 5–12 ml **I** soln. Acidified sample must be titrated rapidly while still hot. At end point vol. of H_2SO_4 added must be at least $\frac{1}{4}$ of tot. vol. of titrated sample mixt. For H_2O contg. as high as 500 mg/l $NaNO_3$, titers equal to 0.1–0.5 mg/ml $NaNO_3$ (corresponding approx. to 0.5–1.0 g/l **I**) are used. For prepn. of **I** soln. **I** should be cautiously wet with concd. H_2SO_4, 6–8 ml acid per g of **I**. Mixt. should be heated on H_2O bath, with frequent stirring, to complete soln. Mixt. is then dild. cautiously with H_2O to known vol. After 5–6 days soln. is filtered and titer detd. against std. $NaNO_3$ or KNO_3 soln. With samples contg. as high as 200 mg/l $NaNO_3$ std. $NaNO_3$ soln. should contain 100 ml/l; for samples contg. 100–500 mg/l $NaNO_3$ std. $NaNO_3$ soln. contg. 300 mg/l is used. **I** soln. keeps its titer 5–6 mos without storage precautions. 10 samples contg. 20–164 mg/l $NaNO_3$ were analyzed by sulfophenol and by **I** method. If sulfophenol results are correct relative error was zero–5.8%.—*CA*

Detection of Nitrites and Nitrates, Alone or Combined, in Very Dilute Solutions. F. A. STEENSMA. Chem. Weekblad (Amsterdam), **53**:10:110 ('57). Addn. of soln. of benzidine in acetic acid to soln. of nitrite gives yellow-red coloration, perceptible at concns. of 0.0002 mg/ml nitrite. Nitrate can be detd. after reduction with alkali and

(*Continued on page 80 P&R*)

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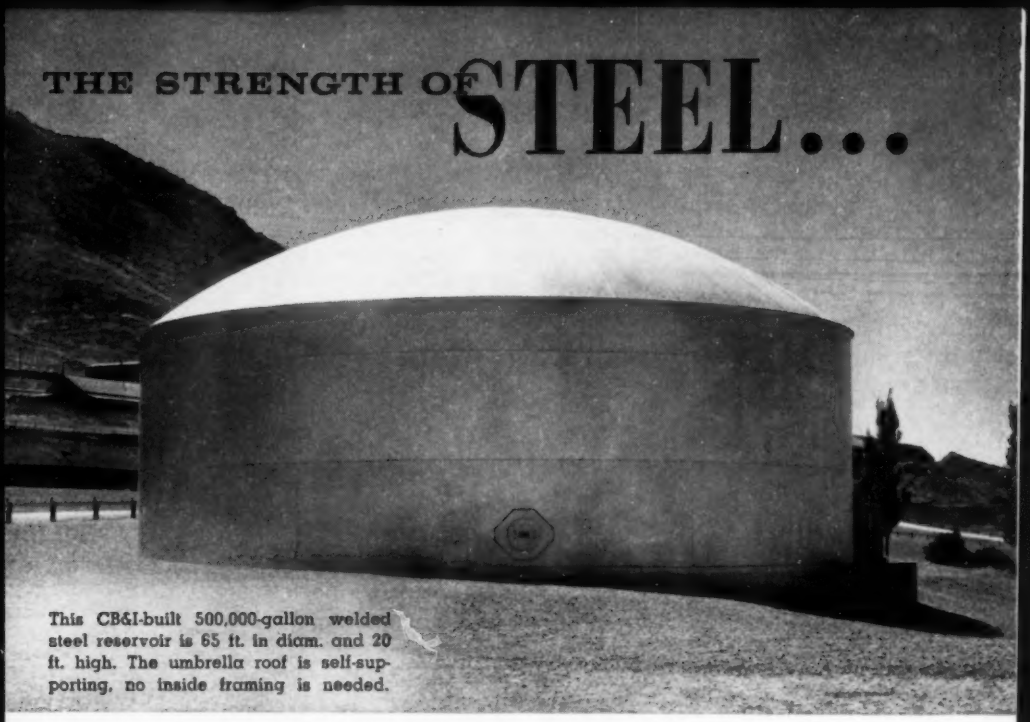

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(*Continued from page 78 P&R*)

zinc dust and treatment with acetic acid. Concn. of nitrate of 0.02 mg/ml can be detected. If nitrite and nitrate are both present in soln. nitrite is removed by treatment with hydrochloric acid and urea, soln. is then made alk. and tested for nitrate. Low pH value reduces sensitivity of reaction.—*WPA*

The Problem of Oxidation of Nitrite With Subsequent Assimilation of Carbon Dioxide by *Nitrobacter Winogradskyi* Buch. E. REMER. Arch. Mikrobiol. (Berlin), **27**: 125 ('57). Expts. are described, using Warburg technique and tracer method with carbon dioxide labelled with carbon-14 on oxidation of nitrite to nitrate by *Nitrobacter winogradskyi* and subsequent absorption of carbon dioxide. After oxidation of nitrite in absence of carbon dioxide bacteria were unable to assimilate carbon dioxide, showing that *Nitrobacter* is unable to store energy obtained by oxidation and subsequently to use it for synthetic processes.—*WPA*

Determination of Organic Nitrogen in Water, Sewage, and Industrial Wastes. G. B. MORGAN; J. B. LACKEY; & F. W. GILCREAS. Anal. Chem., **29**:833 ('57). Modified Kjeldahl method by using H_2SO_4 in place of $KH(IO_3)_2$, gives 98.4% recovery of org. N with std. deviation from avg. of 0.235%. Such recovery is 7% higher than that obtained with CuO-Kjeldahl method. Presence of NO_3^- and NO_2^- has no appreciable effect on detn. of org. N.—*CA*

Experimental Study on the Time Variation of Oxygen Content of Natural Water. Y. SUGIURA. Papers Meteorol. and Geophys. (Tokyo), **7**:42 ('56). Exptl. results verify previous theoretical predictions regarding diurnal variation of DO in hydrosphere. Pond water contg. flourishing phytoplankton pop. is illuminated with incandescent lamp and O cont. is compared with that in same water kept in dark, with pond water dild. ½ with distd. water, and with distd. water. Min. O cont. occurs shortly after commencement of illumination and max. shortly before time of extinction when changes due to phys. factors, such as diffusion, advection, and/or convection, are elimd. Amplitude of variation in O cont. is almost directly proportional to pop. of phytoplanktons and to amt. of light. Max. O cont. occurs earlier in layer closest to surface because of escape into air. Below depth of 20 cm exptl. time variation agrees with theory.—*CA*

Infrared Spectrophotometric Determination of Traces of Parathion in Water. Y. SUMIKI & A. MATSUYAMA. Bul. Agr. Chem. Soc. Japan (Tokyo), **21**:329 ('57). Parathion (**I**) in water sample was extracted into 2–4 l. of solvent (equal vol. mixt. of benzene and hexane). Extract was concd. 1st by vacuum evapn. and then by agitating evaporator. 2 separate chromatographic systems by descending method were employed for isolation of **I**: (1) soybean oil as stationary solvent and either EtOH-nitromethane (4:1 by vol.) or only EtOH as mobile solvent, (2) ethylenechlorohydrin-MeOH mixt. (1:1 by vol.) as stationary solvent and *n*-hexane as mobile solvent. 1st system was used to separate **I** from EPN and 2nd system for sepn. from other insecticides except EPN. Spot of **I** was eluted with ether and detd. by infrared spectrum at 7.37, 9.75, and 10.90 μ. Recovery was 94%.—*CA*

Detection of Petroleum Products in Natural Waters by Means of Fluorescence. B. NIETSCH. Mikrochim. Acta (Vienna), **(1–3)**:171 ('56). Importance of obtaining information on contamn. of natural waters by petroleum products is discussed. Method is described by which down to 1 μg/l petroleum products may be detected by measurement of their fluorescence in ultraviolet light. Sample is shaken with ≃10 mg MgO per 100 ml and filtered MgO absorbs oil. Filter paper is spread on clock-glass and examd. under ultraviolet light (blank detn. is treated similarly). Filtrate is tested under ultraviolet light for complete removal of oil traces. Alternatively, sample is shaken with light petroleum and extract is examd. in ultraviolet light.—*PHEA*

Colorimetric Determination of Small Amounts of Phenol in Water by Means of 2:6-Dichloro-*p*-benzoquinonechlorimine. E. A. BOZHEVOL'NOV. Trudy Vsesoyuz. Nauch.-Issledovatel. Inst. Khim. Reaktiv. (USSR), **21**:38 ('56). Procedure is described for detn. of phenol in water based on reaction of sodium phenolate with 2:6-

(*Continued on page 82 P&R*)

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(Continued from page 80 P&R)

dichloro-*p*-quinonechlorimine to give sodium 2:6-dichlorophenolindophenoxide, which is intensely blue in alk. soln. Color is measured after 2 hr in photoelectric colorimeter using red filter. Reaction is sensitive to 10^{-6}% phenol in water. It can be made sensitive to 10^{-8}% phenol by extracting colored complex with 25 ml isoamyl alcohol free from furfuraldehyde. Reaction is more specific than that with diazotized sulfanilic acid; 1- and 2 naphthol, quinol, pyrogallol, pyridine, and *p*-cresol do not interfere.—*WPA*

Determination of Phenolic-Type Compounds in Water and Industrial Waste Waters. I. Comparison of Analytical Methods. E. F. MOHLER JR. & L. N. JACOB. Anal. Chem., **29**:1369 ('57). Methods for detg. small amts. of phenolic-type compds. were evaluated: (1) Gibbs method, (2) nitrosophenol, (3) 4-aminoantipyrine, (4) infrared, and (5) ultraviolet. Method **1** is based on formation of dibromoindophenol dyes when 2,6-dibromoquinone chlorimide condenses with phenolic compds. having an open para position in buffered alk. soln. Method **2** is colorimetric means of detg. *o*-, *m*-, and *p*-substituted phenols. Method **3** is based on formation of antipyrine dyes. Method **4** is based on bromination of acidified sample, reaction of excess Br with $Na_2S_2O_3$ and extraction of brominated derivatives with CCl_4. Method **5** makes use of bathochromic shift by which ionized phenols show shift of absorption band to longer wavelength with increase in pH. Method **3** is fastest and most precise and accurate even in low ppb range. Method **5** appears to offer considerable promise because it overcomes serious deficiency of other methods—becoming insensitive if coupling position is blocked. —*CA*

Determination of Soluble Phosphate and Total Phosphorus in Sea Water and of Total Phosphorus in Marine Muds. J. D. BURTON & J. P. RILEY. Mikrochim. Acta (Vienna), 1350 ('56). In detn. of phosphate in sea water it has been found that *p*-methylaminophenol sulfate at 100°C is better reducing agent than stannous chloride for

(Continued on page 84 P&R)

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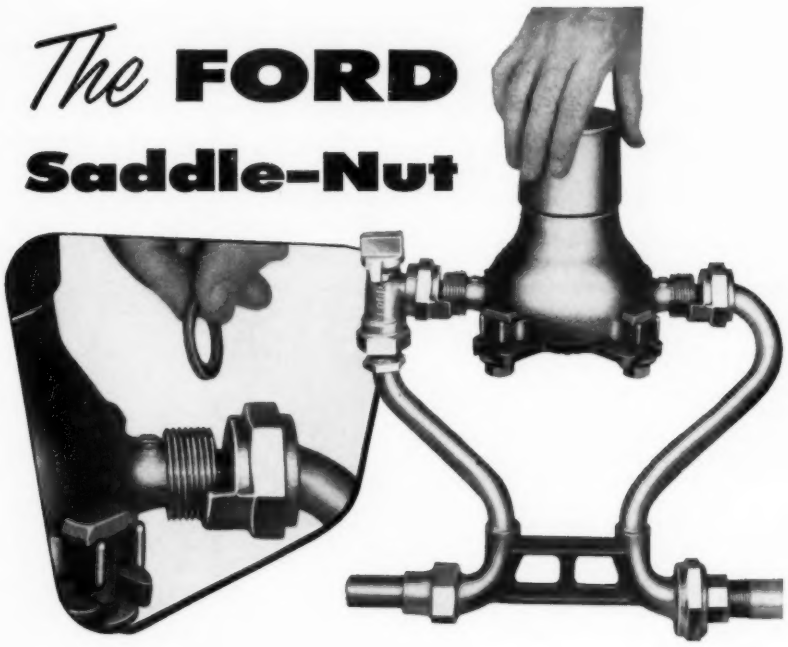

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(*Continued from page 82 P&R*)

reduction of phosphomolybdic acid. Molybdenum blue, when formed, is stable for several hr and calibration curve is not dependent on batch of reagent used. Beer's Law is obeyed for concns. as high as at least 1 mg/l phosphate-phosphorus. Error due to salt concn. is small, and accuracy is about 30% better than when stannous chloride is used. There is no interference by arsenic in concns. likely to occur in sea water nor by moderate concns. of iron and copper. Tot. phosphorus in sea water and marine muds can be detd. by evapg. sample to dryness with nitric and perchloric acids and detg. inorg. phosphate in residue.—*WPA*

Determining Potability of Water Supplies in the Field. H. J. FOURNELLE. US Armed Forces Med. J., **8**:713 ('57). In Alaska, where large numbers of water samples for bact. examn. have to be sent by air, long delays between collection and incubation are unavoidable. Study was made of inoculation of samples directly into primary medium in field. Inoculated tubes, with corresponding water samples, were sent to lab. for examn. Inoculation of media in field was usually accomplished within 1 hr of collection and examn. of same samples in lab. occurred from 6 hr to 14 days later. Approx. $\frac{1}{3}$ of samples which were positive by field procedure were negative when sample was not inoculated until it reached lab. This indicates advantages of early inoculation, to place coliform organisms in environment suitable for growth.—*WPA*

Modified Determination of Radium in Water. F. B. BARKER & L. L. THATCHER. Anal. Chem., **29**:1573 ('57). Ra in H_2O is detd. by pptn. with $BaSO_4$ carrier. Samples contg. <350 mg Ca are dild. to 1 liter and adjusted to pH 3 with HCl. Blank and 2 stds. contg. Ra^{226} are also prepd. Solns. are heated, 7.5 mg of $BaCl_2 \cdot 2H_2O$ is added, 15 ml (400 g/l) of $(NH_4)_2SO_4$ soln. is added, with stirring. Each ppt. is digested 4 hr at room temp., collected on black hydrosol-assay molecular filter membranes, and washed with H_2SO_4 dild. 1:200. Ppt. is aged 10–12 days after drying, and the α activity is measured. As little as 0.1 $\mu\mu$c. of Ra can be detected. Ra^{223} and Ra^{224} are detd. with eff. of 110% but Ra^{228} is not detected. Isotopes can be carried with ppt. but this causes positive error which is not serious in detg. potability of H_2O.—*CA*

The Determination of the Concentrations of Solutions of Reagents at Water Treatment Plants. V. YU. VOINITSKII & B. S. ROGATSKIN. Energetik (Moscow), **5**:4:16 ('57). Instrument described consists of beam balanced on knife edge from end of whose horizontal right arm of length l, is suspended float of wt. G and vol. v. Left arm, bent down at angle α, is loaded with wt. P suspended at point l distant from fulcrum. As G is immersed in soln. tank its buoyant force shifts both arms through angle β. Relation is $P\ l \cos(\alpha + \beta) = (G - v\rho) \cos \beta$ where ρ is sp gr of soln., that is to say, function of its concn.—*CA*

An Instrument for the Measurement of Salinity in Estuaries. E. G. SANDELS. J. Sci. Instr. (London), **33**:424 ('56). Instrument has been developed at Hydr. Research Station, Wallingford (Br.), for measurement of salinities in estuaries. Temp. and elec. cond. of sample pumped thru instrument from intake lowered into estuary from boat are measured separately, and salinity is detd. from nomogram relating these 2 quants. Radio-frequency circuits are employed for measurements. Full description of instrument is given, illustrated by circuit diagrams and method of operation and calibration is described. Instrument has accuracy of $\pm\frac{1}{2}$ part/1,000 over salinity range of 0.2–50 part/1,000.—*WPA*

Salt Concentrator for Testing Feedwaters and Condensates. S. I. ALENCHIKOV & F. K. EVZEROVA. Teploenergetika (Moscow), **3**:5:22 ('56). Test water is passed successively through 2 stages of heat exchange, each followed by flashed liquid-vapor sepn. Arrangements are included in app. for efficient thermal reuse of flashed steam. Final liq. conc. discharge rate is $\frac{1}{10}$ initial feed liq. rate. This reduction in vol. plus the associated degasification substantially increases sensitivity of subsequent salt-cont. test.—*CA*

Taking Water Samples in Flowing Waters. O. JAAG; H. AMBUHL; & P. ZIMMERMANN. Schweiz. Z. Hydrol. (Switz.), **18**: 1:156 ('56). Author describes 3 simple types of water sampling app. made of light metal and easily constructed. They are: horizontal dipping flask of $\frac{1}{2}$–1 liter capac.; microdipping flask of 40-cc capac.; and sam-

(*Continued on page 86 P&R*)

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(*Continued from page 84 P&R*)

pling rod of 30–35-cc capac., for use in places of difficult access, for example mountain streams.—*CA*

Comparative Evaluation of Some Indicators of Sea Water Pollution. N. N. ALFIMOV. Gigiena i Sanit. (Moscow), **22**: 1:25 ('57). Most sensitive test for poln. of sea water is 5-day BOD. Consumption of neutral $KMnO_4$ can also be used. Concn. of NH_3 and of HNO_2 are not trustworthy since they may be consumed by organisms in water.—*CA*

Spectrophotometric Determination of Silica in Mineral Waters. C. MILANI. Chimica e ind. (Milan), **38**:587 ('56). Spectrophotometric detn. of silica cont. of mineral waters permits distinction of ionic and colloidal SiO_2. Tot. SiO_2 cont. of unknown sample is detd. by gravimetric procedure. Calibration curve is then plotted showing variation of optical density with concn. of SiO_2 from observations on known std. samples of $Na_2SiO_3 \cdot 9H_2O$ solns. with increasing concn. Unknown sample is then acidified with $2N$ H_2SO_4 to pH of 1.5 and 10% NH_4 molybdate soln. is added to full development of color. Absorption spectrum of newly formed silicomolybdic complex is then measured and compared with corresponding point on calibration curve. Resulting concn. of SiO_2 is measure of ionic SiO_2 cont. of unknown; colloidal SiO_2 is obtained by difference from tot. SiO_2. Exptl. results of the anals. of mineral waters from various sources and several curves are given.—*CA*

The Accuracy of Particle-Size Determination by Cumulative Sedimentation Methods. J. K. DONOGHUE. Brit. J. Appl. Phys. (London), **7**:333 ('56). It has sometimes been suggested that cumulative methods of particle-size anal. are inaccurate because it is necessary to differentiate sedimentation curve in order to evaluate size distr. By considering hypothetical distr. it has now been shown that if sufficient points are obtained to enable sedimentation curve

(*Continued on page 88 P&R*)

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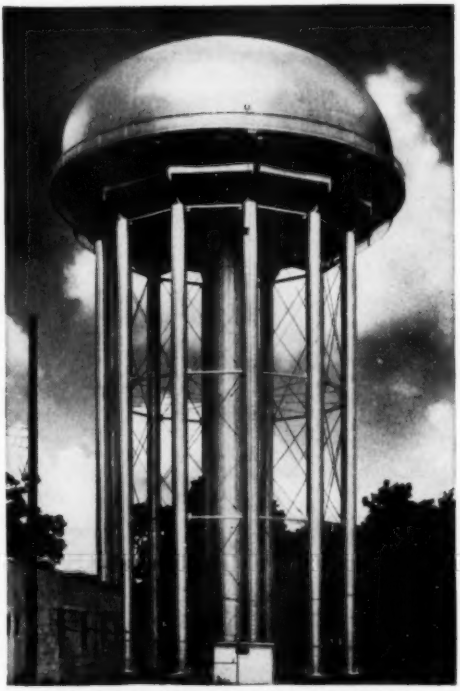

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(Continued from page 86 P&R)

to be plotted accurately this differentiation does not give rise to errors. This was confirmed by comparative tests with microscope and sedimentation balance on 2 samples composed of spherical particles.—*WPA*

Determination of Sodium and Potassium Ions in Acid Springs by Ion-Exchange Chromatography and Flame Spectrophotometry. Y. MASHIKO. Yakugaku Zasshi (Tokyo), **76**:1272 ('56). Sample water contg. about 0.003*M* equiv. of cation was accurately analyzed by passing it thru column (1 × 15 cm) of Amberlite IR-120 (H-type); cation was liberated by washing with 0.5*N* HCl, discarding 1st 10 ml effluent, and effluent was collected in 50-ml and 100-ml flask. Amts. of Na^+ and K^+ were detd. by flame spectrophotometer.—*CA*

Complexometric Determination of Sulfate Ion Using Diethylenetriaminepentaacetic Acid. E. WANNINEN. Suomen Kemistilehti (Finland), **29**:B:184 ('56). In detn. of sulfate excess barium chloride is added to sample and excess barium is titrated with trisodium salt of diethylenetriaminepentaacetic acid (DTPA) in presence of magnesium-DTPA and Eriochrome black T. This method is superior to that using ethylenediaminetetraacetic acid because barium-DTPA complex is more stable.—*WPA*

A Rapid Spectrophotometric Method for Determination of a Minute Amount of Vanadium in Natural Waters. H. NAITO & K. SUGAWARA. Bull. Chem. Soc. Japan (Tokyo), **30**:799 ('57). Trace amts. of V in water are concd. and detd. by a 3-step procedure consisting of (1) copptn. of V with $Fe(OH)_3$, (2) sepn. of V from coprecipitant, and (3) detn. of V oxinate by measuring optical density at 475 mμ. No Fe or Al ppts. from tartrate-NaOH soln. that is kept below room temp. pH is raised to 10.8 or more and then soln. is warmed so that Fe and Al ppt. without causing trace of V.—*CA*

Determination of Zinc in Water. M. F. DOBROVOL'SKII; V. I. KOROLEVA; & P. M. KOZAREZENKO. Gigiena i Sanit. (Moscow), **21**:9:83 ('56). Method depends on formation of Zn complex with dithiazone in $CHCl_3$ followed by its decompn. by HCl and polarographic detn. of Zn in resulting soln. Water kept in galvanized containers may contain $1–2 \times 10^{-4}$ g/l Zn ions.—*CA*

Complexometric Estimation of Sulfate With Phthaleincomplexone. B. PHILIPP & H. HOYME. Faserforsch. u. Textiltech. (Berlin), **7**:525 ('56). Sulfate in aq. soln. may be detd. by pptg. as barium sulfate and either titrating barium directly with disodium salt of ethylenediaminetetraacetic acid (EDTA) using phthaleincomplexone as indicator, or replacing barium with zinc or magnesium before titration with EDTA using Eriochrome black T as indicator. Effect on accuracy of method, of presence of sodium chloride, sodium bromide, sodium thiosulfate, sodium sulfide, and iron has been detd.—*WPA*

The Determination of Sulfates in Potable Waters. M. PIERI. Chimica (Milan), **12**:200 ('56). Comparative expts. of detn. of SO_4^{--} by gravimetric, volumetric, iodometric, colorimetric, potentiometric, and nephelometric methods show that exact results are obtained by potentiometric methods, but volumetric method with I is simplest and most rapid.—*CA*

Volumetric Determination of Sulfate Ion in Water. M. S. IBERTIS ACUNA. Rev. Sanit. Nacion (Buenos Aires), **20**:30 ('56). Sulfate ion was detd. volumetrically by addn. of excess 0.02*N* $BaCl_2$ soln., approx. titration to Eriochrome Black T end point with 0.02*N* Versene, addn. of 2 ml 0.02*N* $MgCl_2$, and finally accurate titration with addnl. 0.02*N* Versene. Results by this method were found to be as accurate as gravimetric method for concns. between 10 and 250 mg/l sulfate. Copper interferes with end point if present in amts. >0.2 mg/l. Ferric iron in amts. as great as 10 mg/l does not interfere.—*CA*

Transport Problems in Public Health Bacteriology. R. D. STUART. Can. J. Public Health (Toronto), **47**:114 ('56). Prob'em of transporting specimens to distant labs. for bact. examn. without signif. alteration in original bact. cont. is discussed. Methods in current use or on trial in provincial Lab. of Public Health, Univ. of Alta., are described. For transport of water samples requiring examn. of their fitness for use as domestic supplies convenient container for mailing without refrigeration is used. Container holds 5 sterile, screw-cap phials filled to within 10 cc of top with concd. MacConkey broth, each of which is filled with water to be tested. On arrival at lab. samples require only incubation and method permits more accurate detn. of presence and density of fecal bacteria.—*WPA*

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To the Editor:

On the program of the Fifteenth Annual Meeting of the Colorado River Water Users' Assn. a prominent feature was the Percolation and Runoff Conference, held in the Portrait Room of the Riviera Hotel from 6 to 7 PM.

As to the use of "Percolation and Runoff" as the now time-honored name for the annual cocktail hour, I freely plead guilty to plagiarizing the JOURNAL, but defend myself on the ground of practical necessity. You see, when the annual convention of the Association was held in Salt Lake City some years ago, I, as the legman, was called upon to advertise a cocktail hour by means of placards in the hotel lobby. Now, in "semi-arid" Utah, we just don't do that sort of thing, don'cha know. So I solved the problem by this simple bit of literary larceny, and the name so appealed to the membership that it has stuck ever since.

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Dec. 16, 1958

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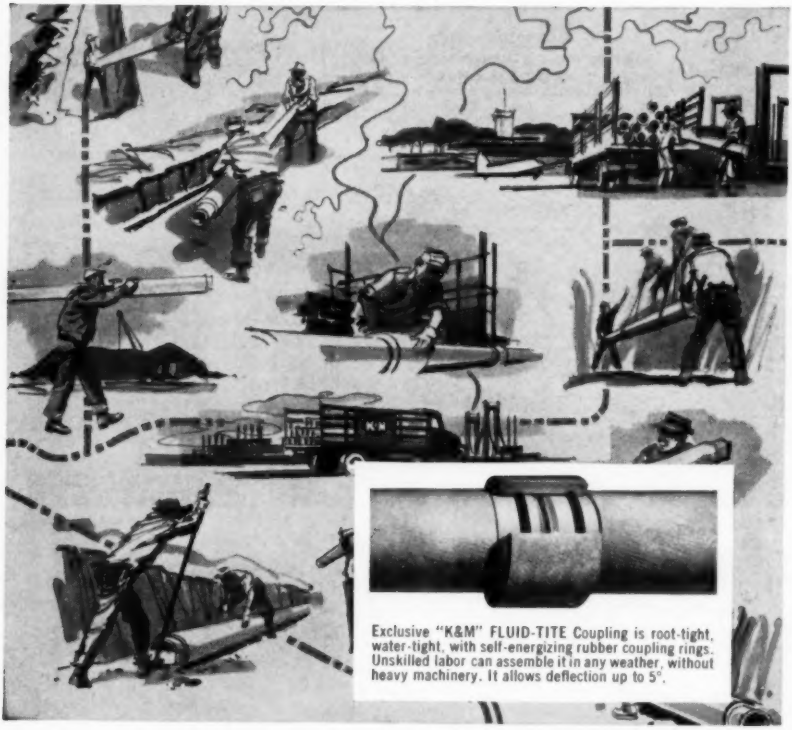
Exclusive "K&M" FLUID-TITE Coupling is root-tight, water-tight, with self-energizing rubber coupling rings. Unskilled labor can assemble it in any weather, without heavy machinery. It allows deflection up to 5°.

FROM KEY WEST TO L.A.

Modern communities are joining the trend to the modern pipe—"K & M" ASBESTOS-CEMENT PRESSURE PIPE with FLUID-TITE COUPLING

• Permanent, root-tight, water-tight connections • Non-tuberculating • Non-electrolytic • Corrosion-resistant • Longer sections—fewer joints • Pumping costs remain low • Your low first cost is often your last cost.

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COMPANY • AMBLER • PENNSYLVANIA

K·M
BEST IN ASBESTOS

EXTENSION OF
WATER WORKS FILTRATION PLANT
Mobile, Alabama
JOHN A. STALCUP, Supervisor of Water Production
Consulting Engineers
J. B. CONVERSE & CO., Mobile, Alabama

A credit to its neighborhood, this modern building houses the expanded facilities which increase plant capacity from 20 MGD to 30 MGD . . . with an emergency capacity of 40 MGD.

Modern Builders Filter Control Tables centralize filter operations . . . save steps, conserve manpower, permit absolute control. Easy-to-read, conveniently located gauges simplify operator's job.

Builders Master Control System regulates level in settling basins. Filters (not shown) are equipped with Builders Wheeler Monolithic underdrains of concrete with porcelain spheres. They're as durable as the plant itself.

ONE SOURCE
ONE RESPONSIBILITY

B-I-F

B-I-F INDUSTRIES
BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA

POSITIVE CONTROL OF MATERIALS IN MOTION BIF METERS FEEDERS CONTROLS

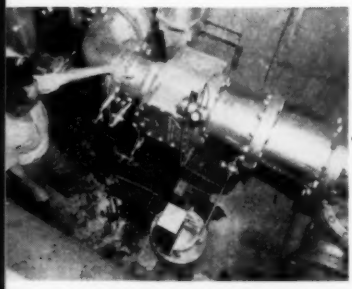
Water Treatment Plant Expanded . . . SINGLE, RESPONSIBLE SOURCE FURNISHES CONTROLS and CHEMICAL FEEDERS

Performance, quality and economy influence decision to use B-I-F products in latest plant addition in Alabama.

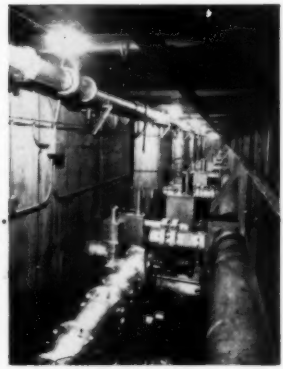
Mobile, one of the South's fastest growing cities, recently had to double the capacity of their Water Filtration Plant. After thoroughly exploring all aspects of such an important undertaking, Mobile decided on a reputable multi-product manufacturer of equipment already proven in the original plant.

Better coordination, through B-I-F's ability to offer a ONE SOURCE — ONE RESPONSIBILITY policy, brought immediate savings . . . during the installation and start-up stages. Fast, convenient service through local offices was another deciding factor.

If greater systems reliability and operating economies interest you, write for details . . . to **B-I-F Industries, Inc., Utilities Sales, 365 Harris Avenue, Providence 1, Rhode Island.**



Builders Pneumatic Master Control System simply and rapidly provides remote rate-of-flow setting.



Ten Builders Rate-of-Flow Controllers were furnished. Self-actuated, they conserve head, promote filter efficiency, provide long life, assure accurate flow.

Omega Chemical Feeders were selected because of their 100:1 feed range at high accuracy.

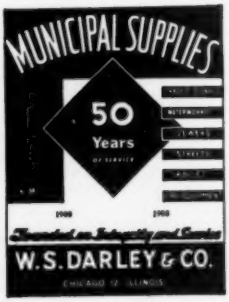
(*Continued from page 50 P&R*)

F. G. Fabian Jr. has been named president of Dresser Mfg. Div., Bradford, Pa. He has held the post of general manager since 1955. The division of Dresser Industries, Inc., supplies pipe joining and repair products, as well as industrial rings, weldments, and components.

General Waterworks Corp. has sold its holdings of 74,000 common shares of Consumers Water Co. of Portland, Me.

Water for Tea has been assured by a federal loan of $27,500 negotiated early in October. Water for Coats, meanwhile, is to be financed by a local bond issue. Obviously water is more needed for Tea than for Coats—the latter being supplied by a privately owned water system, the former, by hand. But now, having voted 3–1 in favor of a system of its own, Coats is in Tea's boat, the private supplier having discontinued service upon learning of the vote that would put him out of business soon anyway. Failing to coax, Coats is going to court hoping to force resumption of service until it can force its cessation. Tea, accustomed to bucket baths and demijohn drinking, is thus temporarily in better shape than Coats. Both Tea's 151 South Dakotans and Coats' 1,200 North Carolinians should appreciate their water when they get it—it always has been necessary for tea and good for coated tongues.

(*Continued on page 96 P&R*)



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THE HEAVY-DUTY
ELLIS
PIPE CUTTER
IS *BEST*

FOR CUTTING LARGE SIZES OF PIPE

No. 01 Cuts Pipe 4" to 8"
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Write for circular and price list No. 40J on our complete line of pipe cutting tools.

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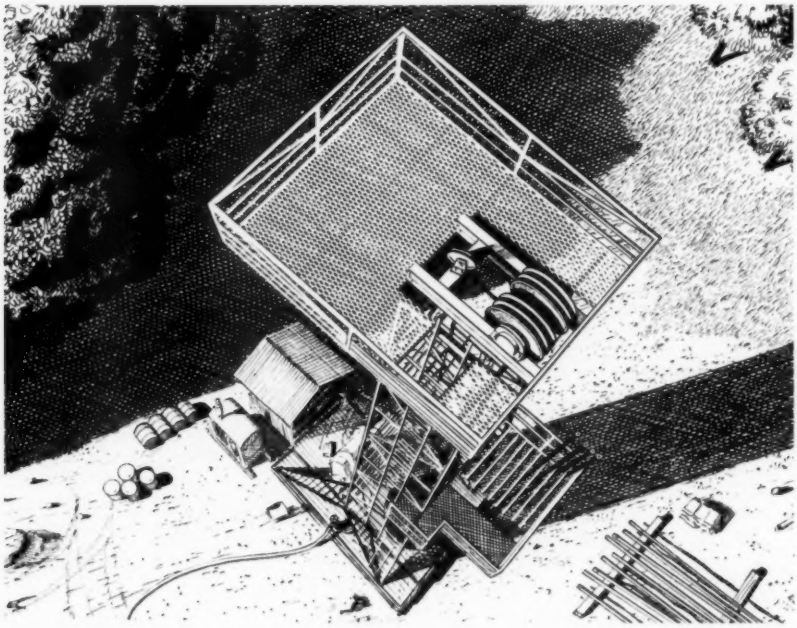


RIGHT...from the top down

A good, dependable water supply system is no better than its beginning. The best beginning is a Layne drilled water well. Layne is the largest water well drilling organization in the world with over 75 years experience. Trained crews operate over 500 drilling and service rigs throughout the country.

Layne service doesn't stop there. A dependable Layne Pump specially designed for the job to deliver a specified QUANTITY of water, and Layne water treatment service to supply the exact QUALITY of water desired, are part of a complete job with undivided responsibility. But, that's not all. Layne maintenance and repair service wraps up the complete package. Your nearby Layne Company is as close as your telephone, so, call on Layne for a dependable water supply, right . . . . . from the top down, all backed by Layne Research.

Layne **WELL DRILLING**

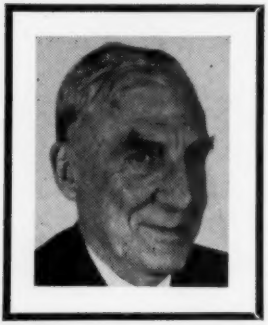
and other allied Drilling Services

LAYNE & BOWLER, INC., MEMPHIS

Offices and Factory, Memphis 8, Tennessee

Water Wells • Vertical Turbine Pumps • Water Treatment

(Continued from page 94 P&R)



G. Gale Dixon, associate in the consulting engineer firm of Parsons, Brinckerhoff, Hall & Macdonald, New York, died Dec. 6, 1958, at the age of 73. Born in New York in 1885, he was graduated from the College of the City of New York in 1907. Prior to joining the New York firm in 1941, he engaged in private consulting practice, was a partner in the engineering concern of Barbour & Dixon, Boston, served with the Tennessee Valley Authority and the Pennsylvania Water & Power Resources Board, and was a member of the board of review appointed by Interior Secretary Ickes to advise on plans for Chicago's West-Southwest Sewage Treatment Works. At JBHM, he was chief sanitary engineer, responsible for all of the water and sewerage projects handled by the firm in the United States and South America. Many features of his water system designs have been regarded as advances in the art and widely adopted. A Life Member of AWWA (joined in 1920), Mr. Dixon also belonged to ASCE, FSIWA, and NEWWA.

Edward A. Fowler, former engineer with the New Orleans Sewerage & Water Board, died Oct. 16, 1958. He was a Life Member of AWWA and the oldest member of the Southwest Section, having joined in 1910.

Theodore Horton, former chief sanitary engineer with the New York State Dept. of Health, died Dec. 7, 1958, at his home in Sandwich, Mass. He was 87. Born in Plattsburg, N.Y., in 1871, he received a degree in sanitary engineering from Massachusetts Institute of Technology in 1894. In 1901, after service as a health officer at Montclair, N.J., and as an engineer with the Brooklyn, N.Y., Dept. of Public Works, the Massachusetts State Board of Health, and the Metropolitan Sewerage System of Massachusetts, he accepted a position as principal assistant engineer with the consulting firm of Hering & Fuller, New York. In 1906 he was appointed chief engineer of the New York State Dept. of Health to head the newly established Sanitary Engineering Div. There he pioneered in public health engineering, especially in the field of polltion control. He retired in 1936. A Life Member of AWWA (joined in 1907), his other professional affiliations included ASCE, APHA, and Boston Society of Civil Engineers.

Will A. Hutchins, retired superintendent of the Freeport, Ill., Water Dept., died Oct. 25, 1958, at the age of 69. Born in Orangeville, Ill., in 1889, he attended the University of Illinois. In 1912 he joined the Freeport Water Co., which then operated the water system, as a meter reader. By 1920 he had risen to superintendent, a position he held until his retirement in 1956. He was a Life Member of AWWA (joined in 1920).

(Continued on page 98 P&R)

WATER FOR U.S. AIR FORCE ACADEMY

29,000 feet of Armco Pipe delivers water across mountainous area

The United States Air Force Academy, like hundreds of American cities, relies on Armco Welded Steel Pipe for water supply lines. Shown here is part of the 29,000 feet of Armco Pipe being installed to carry water from Colorado Springs to the Academy. This water line was laid during the winter over rough mountain terrain. Even so, the job was completed on schedule.

Armco Pipe can help solve *your* water supply problems too. Linings and coatings are supplied according to AWWA Standard C-203. Write us for information related to your particular requirements. Armco Drainage & Metal Products, Inc., 5099 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation. In Canada: write Guelph, Ontario.

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OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division
The National Supply Company • The Armco International Corporation
Union Wire Rope Corporation • Southwest Steel Products

(*Continued from page 96 P&R*)

David J. Purdie, New York sales representative of B-I-F Industries, Inc., died Jan. 7, 1959, at the age of 76. Upon graduation from Brown University in 1911 with a B.S. in mechanical engineering, he joined Builders Iron Foundry, the predecessor of B-I-F. He was made district manager, New York office, in 1916. In 1955 he became a consultant to the firm. He retired in 1958. A member of AWWA since 1949, Mr. Purdie also belonged to ASME and the North Jersey Water Conference.

now we're getting some place!

We're making solid gains in the fight against cancer, in the research laboratory, in the hospital and in the home. Ten years ago medical knowledge was able to save only 1 in 4 lives — today it's saving 1 in 3.

New surgical techniques, diagnostic methods, and an informed public are important reasons for these gains.

More and more people have learned that many cancers are curable if detected in time. And, sensibly, more and more people have formed the life-saving habit of an annual health checkup. They know it's living insurance against cancer!

AMERICAN CANCER SOCIETY

Service Lines

Dial thermometers are the subject of a 12-page, two-color catalog recently published. Illustrations, diagrams, and tables are included to describe characteristics of thermometers designed for four types of actuation—mercury, vapor, gas, and liquid. Copies of Catalog 205 are available upon request from U. S. Gauge, Div. of American Machine & Metals, Inc., Sellersville, Pa.

Modernization is the theme of a 20-page booklet that describes, with photographs, various types of equipment available for industry. Entitled "59 Ideas for Modernization in '59," the booklet (No. 25B9084) may be obtained from Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

Controlled-volume pumps, designed for accurate metering of chemicals against pressures as high as 1,900 psi, are discussed in a 2-page leaflet. Bulletin 258, which describes design features, operation, and specifications of the pumps, is available by writing on company letterhead to Milton Roy Co., 1300 E. Mermaid Lane, Philadelphia, Pa.

Ion exchange is the subject of a 60-page handbook recently published. Using charts, graphs, and tables, the booklet discusses the various methods of softening, dealkalizing, and demineralizing, from the standpoint of equipment and chemicals required and the quality of water produced. Copies of "Water Conditioning With Nalcite Ion Exchangers" are available from National Aluminate Corp., Ion Exchange Div., 6315 W. 66th Pl., Chicago 38, Ill.

WORTHINGTON-GAMON

WATCH DOG

The meter used by thousands of municipalities in the U. S.

WATER METERS

"Watch Dog" models . . . made in standard capacities from 20 g.p.m. up: frost-proof and split case in household sizes. Disc, turbine, or compound type.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE.

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

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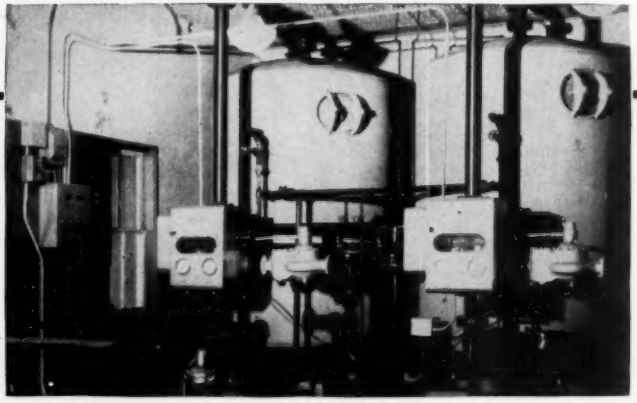

Iron and Manganese Removal Plus Water Softening . . .
Automatically by Ion-Exchange using Invercarb C-110

Low in cost—efficient in operation. Send for Particulars.

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HAMMOND
PROVIDES
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WATER STORAGE
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ALEXANDRIA, LA.

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Capacity	1,000,000 Gal.
Tank Diameter	86 Feet
Range of Head	25 Feet
Tower Height	113 Feet

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consulting engineer
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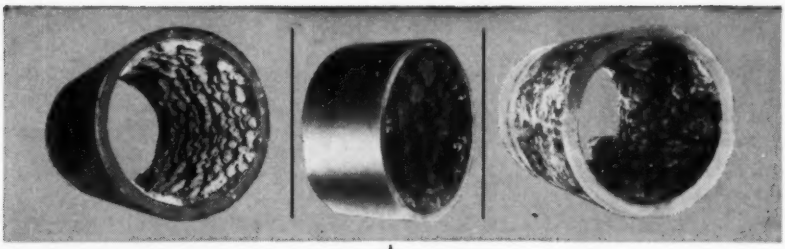

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... it cuts down flow capacities
... it raises pumping costs

this is CALGON®

... it CONTROLS Tuberculation

Water treatment with Calgon brand sodium hexametaphosphate is the simple, economical way to control the corrosion that is so costly to municipal water systems. Reduced capacity and the consequent increase in pumping power are far more costly than Calgon treatment. And Calgon solves other water problems, too.

Calgon treatment is particularly effective after mechanical main cleaning, because its fast film forming ability quickly interposes a barrier between the freshly scoured metal and the corrosive effects of the water.

A report of a 24 month study on the efficiency of Calgon in maintaining pipeline flows is available. Write for a reprint of this paper. A letter or phone call will bring you more information on how Calgon can help. A Calgon engineer will be glad to make detailed recommendations on your specific problem.

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Pittsburgh Equitable Meter Div.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Bailey Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Foster Eng. Co.
Simplex Valve & Meter Co.
Sparling Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
Bailey Meter Co.
Buffalo Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Burgess-Manning Co., Penn Instruments Div.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Sparling Meter Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
F. B. Leopold Co.

Paints:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Concrete Pressure Pipe Assn.
American Pipe & Construction Co.
Lock Joint Pipe Co.
Vulcan Materials Co.

Pipe, Copper:
American Brass Co.

Pipe, Plastic:
Orangeburg Mfg. Co.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Morgan Steel Products, Inc.

Pipe Cleaning Services:
National Water Main Cleaning Co.

Pipe Contings and Linings:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div.
Reilly Tar & Chemical Corp.

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Plugs, Removable:
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Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
Precision Chemical Pump Corp.
Proportioneers, Inc. (Div., B-I-F Industries, Inc.)
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
W. S. Rockwell Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
Bailey Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries, Inc.)
Simplex Valve & Meter Co.
Sparling Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
Ludlow Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.

Sodium Aluminate:
National Aluminate Corp.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride:
American Agricultural Chemical Co.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
John Wiley Jones Co.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Sodium Silicofluoride:
American Agricultural Chemical Co.
Tennessee Corp.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
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General Filter Co.
Industrial Chemicals, Inc.
International Salt Co., Inc.
National Aluminate Corp.
Permutit Co.
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Morgan Steel Products, Inc.
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Mueller Co.

Storage Tanks: see Tanks

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Permutit Co.

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Omega Machine Co (Div., B-I-F Industries, Inc.)
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Wallace & Tiernan Inc.

Tanks, Restressed Concrete:
Preload Co., Inc.

Tanks, Steel:
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Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Morgan Steel Products, Inc.
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Tapping-Drilling Machines:
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Mueller Co.
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Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.

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General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Permutit Co.
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Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
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Turbines, Steam:
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DeLaval Steam Turbine Co.

Turbines, Water:
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DeLaval Steam Turbine Co.

Valve Boxes:
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Ludlow Valve Mfg. Co., Inc.
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Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
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A. P. Smith Mfg. Co.

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Ross Valve Mfg. Co., Inc.
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James B. Clow & Sons
DeZurik Corp.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
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Mueller Co.
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Hersey Mfg. Co.

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James B. Clow & Sons
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Golden-Anderson Valve Specialty Co.
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Mueller Co.
Henry Pratt Co.
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A. P. Smith Mfg. Co.
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Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co., Inc.

Valves, Gate:
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James B. Clow & Sons
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
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Mueller Co.
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A. P. Smith Mfg. Co.
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Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
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Ludlow Valve Mfg. Co., Inc.
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Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
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Valves, Regulating:
DeZurik Corp.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co.
S. Morgan Smith Co.

Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
W. S. Rockwell Co.
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R. D. Wood Co.

Venturi Tubes:
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Simplex Valve & Meter Co.

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Plastics & Coal Chemicals Div.

Water Softening Plants; see Softeners

Water Supply Contractors:
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Water Testing Apparatus:
LaMotte Chem. Products Co.
W. A. Taylor & Co.
Wallace & Tiernan Inc.

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Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
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Layne & Bowler, Inc.

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Zeolite: see Ion Exchange Materials

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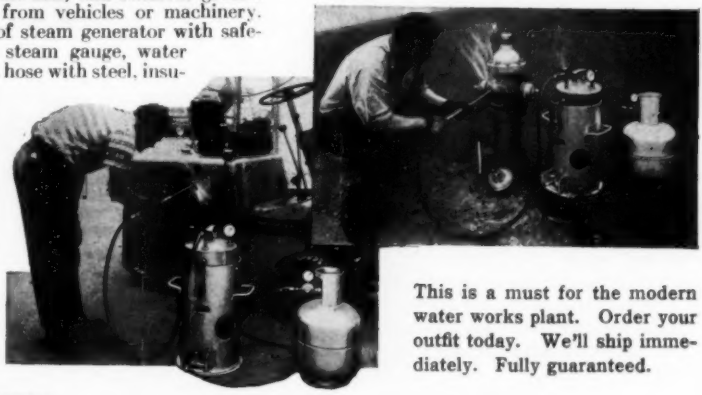

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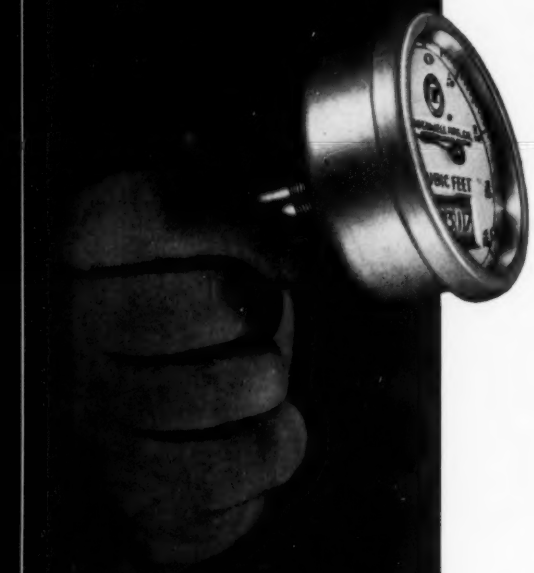

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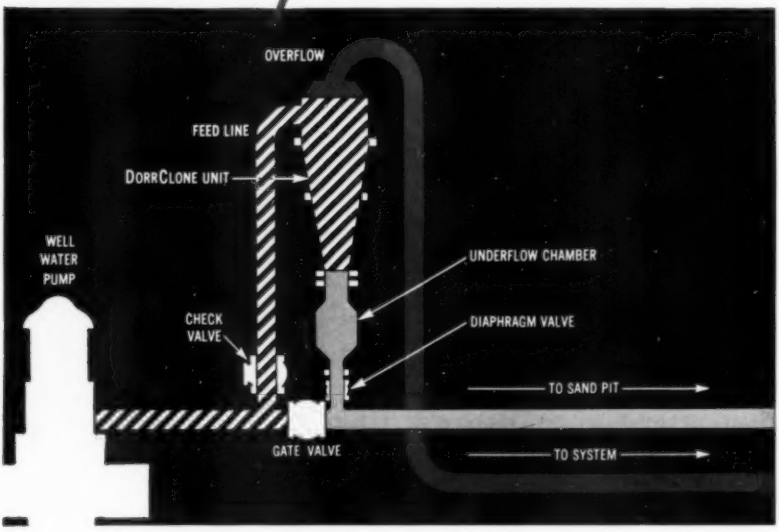

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